# Disaggregated national freight demand modelling in emerging economies

by

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# DECLARATION

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This dissertation includes one original paper published in a peer-reviewed journal, two published peer-reviewed book chapters and three unpublished papers. The development and writing of the papers (published and unpublished) were the principal responsibility of myself and, for each of the cases where this is not the case, a declaration is included in the dissertation indicating the nature and extent of the contributions of co-authors.

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# ABSTRACT

A growing understanding is emerging regarding the pivotal role of freight logistics in sustainably enabling macroeconomic production factors in a globally connected world. This necessitates a novel view of logistics' trade-off role, what is increasingly being referred to as macrologistics, i.e. to lower the total cost of ownership of goods on a macroeconomic scale to improve societal wellbeing and ecological sustainability, implemented through balanced logistics policy, appropriate infrastructure provision and systemic management. This pervasive trade-off characteristic of logistics necessitates the availability of data, i.e. detailed information on transport and its underlying factors based on the interrelations between the transport sector and the rest of the economy. In emerging economies, where macrologistics information is needed the most due to high levels of investment required with a simultaneously high expected impact, this information is scarce and difficult to develop.

The primary aim of this dissertation was to develop a methodology for modelling sectorally and regionally disaggregated freight flows in emerging economies in the absence of formal interrogable statistics on the freight transport market by leveraging existing data sources and successfully applying the outputs to inform macrologistics decision-making, referred to as disaggregated national freight demand models (DNFDMs). A resulting secondary aim is to contribute to the body of knowledge in the developing field of macrologistics in general, and specifically how it relates to emerging economies.

The development of the DNFDM methodology was facilitated by the cyclical process of grounded theory principles, i.e. discovery, collection, coding, analysis, triangulation, and targeted sampling to reach data saturation for the core building blocks of the DNFDM, namely geographically and sectorally disaggregated supply and demand data, and the networks and distance decay factors required for freight-flow modelling. This hands-on, iterative process led to the refinement of the methodology and a deep understanding of its execution in emerging economies. The novelty of the methodology is that the DNFDMs render standardised outputs that are comparable across countries using available statistics in the emerging economy under analysis. These standard outputs are geographically and sectorally disaggregated supply and demand data (aligned with economic aggregates) and resulting freight flows with the primary parameters of origin, destination, commodity, volume of freight and transport mode. The strength is in the *disaggregated* analysis made possible which, despite the onerous data requirements, remains a cost-effective approach for the level of detail rendered and the resources required compared to primary research which can only yield similar comprehensiveness and validity with very large samples.

The methodology was successfully applied in South Africa, India, Mongolia and Uzbekistan and the process and outputs are shared in this dissertation. In all cases the methodology proved sound, the population of supply and demand tables, and subsequent freight-flow modelling, were possible, and the outputs added significant value to the country-level understanding of the national, regional and industry-level freight-flow landscape, informing data-driven policy and infrastructure investments. For each case study country, priority macrologistics interventions were identified that, if diligently verified and implemented, can make a significant shift in the country's macrologistics landscape and unlock resources for addressing subsequent priority areas.

# OPSOMMING

Begrip vir die sleutelrol wat vraglogistiek in die volhoubare ontwikkeling van makroekonomiese produksiefaktore van die wêreld speel, neem toe. Hierdie begrip vereis ‘n nuwe benadering tot logistiek se afruilingsrol, wat toenemend makrologistiek genoem word. Makrologistiek se doel is om die totale makroekonomiese koste van eienaarskap van goedere te verlaag terwyl sosiale ontwikkeling en ekologiese volhoubaarheid verbeter word. Dit word deur gebalanseerde logistieke beleid, die verskaffing van gepaste infrastruktuur, en stelselmatige bestuur bereik. Hierdie alomteenwoordige afruilingsvereiste van logistiek beteken dat data benodig word, wat in hierdie geval data oor vragvervoer, die onderliggende drywers daarvan, asook die onderlinge verwantskap tussen die vervoersektor en die res van die ekonomie beteken. In ontluikende ekonomieë waar meer makrologistieke inligting nodig is om hoë beleggingsvereistes, met ‘n verwagte relatiewe hoë trefkrag, te ondersteun, is hierdie inligting skaars en moeilik om te ontwikkel.

Die hoofdoel van hierdie proefskrif is om ‘n metodologie te ontwikkel wat vragvloeie in ontluikende ekonomieë sektoraal en volgens streke verdeel. Hierdie verdeling is nodig as gevolg van die afwesigheid van formele en bruikbare nasionale vragvervoerstatistieke. Vragvervoerstatistieke kan egter met beskikbare databronne ontwikkel word. Hierdie databronne kan suksesvol aangewend word om sektoraal en geografies verdeelde nasionale vragvraagmodelle (VNVM) te skep wat vir makrologistieke besluitneming gebruik kan word. ‘n Verwante sekondêre doelwit is om ‘n bydrae tot die ontwikkelende teorie van makrologistiek in die algemeen, maar meer spesifiek in ontluikende ekonomieë, te maak.

Die VNVM word deur die gegronde teoriemetode moontlik gemaak: i.e. sikliese ontdekking, versameling en triangulasie van data, ondersteun deur geteikende steekproeftrekking, totdat dataversadiging bereik word. Sodoende word die boublokke van die VNVM, naamlik geografies en sektoraal verdeelde vraag- en aanboddata asook die verwante netwerk en afstandsafnamefaktore, in plek gestel. Hierdie praktiese en iteratiewe proses het tot die verfyning van die metodologie en die aanwending daarvan in ontluikende ekonomieë aanleiding gegee. Die metodologie is uniek, want gestandardiseerde uitkomste, ontwikkel met behulp van plaaslik beskikbare en diverse statistiekinsette, wat tussen lande vergelyk kan word, is moontlik. Hierdie gestandardiseerde uitsette is geografiese en sektoraal verdeelde vraag- en aanboddata wat vragvloeimeting moontlik maak; vragvloeie word dan in oorsprong en bestemming, kommoditeit, volume en vragmodus uitgedruk. Hierdie uitsette, ten spyte van moeilike verkrygbare data en gegewe die detail wat bereik kan word, is ‘n koste-effektiewe benadering in vergelyking met die hulpbronne wat vir primêre navorsing, wat net met groot steekproewe bereik kan word, nodig sou wees.

Hierdie metodologie is suksesvol in Suid-Afrika, Indië, Mongolië en Uzbekistan aangewend en die proses en uitsette word in hierdie proefskrif aangebied. Die metodologie se werkbaarheid is in alle gevalle bevestig, vraag en aanbodmodelle kon saamgestel word, en vloeimodelle kon daaruit afgelei word. Die uitsette het aanleiding gegee tot ‘n beduidende begrip van die nasionale, streek en industriele vragvloeiomgewing wat datagedrewe beleid- en infrastruktuurbesluite moontlik maak. Prioriteit makrologistieke programme is vir elke gevallestudieland geïdentifiseer wat, indien dit pligsgetrou geverifieer en geïmplementeer word, ‘n beduidende verbetering in die land se makrologistieke omgewing kan maak en bronne vir die ontsluiting van hierdie, en ander, programme moontlik sal maak.

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| | |
|---|---|
| ATD | Average Transport Distance |
| BRI | Belt and Road Initiative |
| BRICS | Brazil, Russia, India, China, and South Africa |
| CFS | Commodity Flow Survey |
| DFC | Dedicated Freight Corridor |
| DNFDM | Disaggregated National Freight Demand Model |
| FDM | Freight Demand Model |
| FDI | Foreign Direct Investment |
| FMCG | Fast Moving Consumer Goods |
| GDP | Gross Domestic Product |
| GPS | Geographical Positioning System |
| GRP | Gross Regional Product |
| I-O | Input-Output |
| IMEX | Import Export |
| ITF | International Transport Forum |
| LPI | Logistics Performance Indicator |
| LSP | Logistics Service Provider |
| OD | Origin Destination |
| OECD | Organisation for Economic Co-operation and Development |
| RO | Research objective |
| SEZ | Special Economic Zone |
| UFFM | Uzbekistan Freight Flow Model |
| UN | United Nations |

# Chapter 1. Introduction and research framework

## 1.1 Background

The modern approach to logistics was a result of the most profound macro-economic event of the 20th century, i.e. World War II, where logistics' provision of material and movement support of troops was a key factor in the Allied victory. Post-war, the logistics capability was refocused to enable economic reconstruction (McGinnis, 1992). The principles of logistics progressively gained traction on a business level from the 1960s, maturing as a business discipline towards the end of the 20th century as successful companies leveraged logistics to gain competitive advantage (Stock and Lambert, 2001). The key success factor that unlocked the role of logistics was the development of activity-based cost data to facilitate the optimal implementation of organisational strategy through informing a hierarchy of cost trade-offs. In successful organisations this typically culminated in the formalisation and inclusion of the instrumentation of business logistics in the organisation's decision support systems. This allowed logistics' role to evolve over the past two decades beyond trade-offs between logistics functions (e.g. transport vs. warehousing) to trade-offs between business functions (e.g. production and logistics), towards total cost of ownership trade-offs, first for companies, then total supply chains and finally value chains (Christopher, 2005; Gattorna, 2010).

Over the same period profound changes in the organisation's external environment also took place. Macro-economic issues are dominating the societal discourse. Environmental, societal and economic growth issues are eclipsing the needs of single businesses. There is a growing movement away from the imbalance in the imperative of profit above people (societal) and planet (environmental). The environmental pillar of sustainable development, with early roots as far back as before World War I, albeit in a more fragmented manner (Meyer, 2017), was concretized in the works of Hardin (1968), the Club of Rome (Meadows et al., 1972) and Schumacher (1973), emphasizing the integrated nature of economic decisions, broad environmental impacts and individual wellbeing. Since the rise of humanitarian logistics and the migration crises from Africa and the Middle East towards Europe, and from Central to North America, the people pillar has also gained momentum. Sustainable Aotearoa New Zealand (2009) advanced the debate by proposing that environmental protection and social development take precedence over GDP growth.

Concurrently, a growing understanding is emerging regarding the pivotal role of freight logistics in sustainably enabling macroeconomic production factors in a globally connected world. At the outset, informed by micrologistics successes, the discussions around logistics' contributions to the macroeconomic environment highlighted inventory management (Ramey, 1989; Burger, 2008; Du Plessis and Kotze, 2010). Banomyong et al. (2008) and Skowrońska (2013) emphasised the extension of macrologistics to include infrastructural and policy perspectives. Memedovic et al. (2008) discussed the role of logistics in improving the competitiveness of global value chains. Gleissner and Femerling (2013) expanded the view to what they call 'societal logistics' where the human element is included.

The candidate contributed to the development of this body of knowledge by co-authoring the first book on macrologistics, published in 2020, which aimed to chart the evolution of logistics from micro- to macrologistics, including an instrumentation construct and a view on macrologistics' contribution to a more sustainable future (Havenga et al., 2020). For the purposes of this dissertation, macrologistics is defined as "the optimisation of the time and place discrepancy on a national level". The strategic goal of macrologistics is to lower the total cost of ownership of goods on a macroeconomic scale to improve societal wellbeing and ecological sustainability, implemented through balanced logistics policy, fit-for-purpose infrastructure provision and systemic management. This pervasive trade-off characteristic of logistics necessitates the availability of data.

Statistically significant relationships between logistics performance and international trade (refer e.g. Hausman et al. 2005, 2013; Portugal-Perez and Wilson, 2012), and between logistics infrastructure investment and the strength of a nation's capital production factor (refer e.g. Fedderke et al., 2006; Pradhan and Bagchi, 2013; Song and Van Geenhuizen, 2014) have been demonstrated. Logistics improvements not only increase domestic technical efficiency, defined as 'obtaining the maximum attainable output given the inputs used and technology available' (Coto-Millán et al., 2016) but also lead to rising per capita incomes (Zaman and Shamsuddin, 2017). The Australian Logistics Council (2014) and Rantasila and Ojala (2015) however cautioned that national accounts only capture outsourced activities, i.e. not in-house logistics services, while Weng and Du (2015) urged cost comparisons based on transportable GDP (i.e. agriculture, mining and manufacturing), not total GDP (which includes the services sector that does not require notable physical logistics solutions). Aggregate freight-flow analysis cannot reflect the diversities in the underlying regional and sectoral production or consumption processes in an economy to facilitate targeted investments and efficiency initiatives over the medium and long term to enable the management of transport as a strategic national resource (Tavasszy and De Jong, 2014; Stinson et al., 2017).

Empirical literature on freight demand modelling nevertheless often still focuses on aggregate trade flows (Ivanova, 2014), single industries (Da Silva and de Almeida D'Agosto, 2013; Ottemöller and Friedrich, 2017) or single geographies (De Oliveira and Pereira, 2014) which hampers an understanding of the role of transport in national and regional economic competitiveness and sectoral development (Mačiulis et al., 2009). Five decades ago, Kresge and Roberts (1971) underscored the importance of coupling between the macroeconomic environment, industrial production, final demand and freight transport on a network when developing freight demand models. Their transport model consisted of regional supply and demand, disaggregated into subcommodities, as key inputs for modal choice and routing. This structure was echoed by Van Es (1977) who described two essential characteristics of a freight transport policy information system namely that it must provide actual information on transport and its underlying factors, and that it must be based on the interrelations between the transport sector and the rest of the economy and on the interrelations within the transport sector itself. Samuelson and Roberts (1975) confirmed that the pattern of freight flows is heavily dependent on the type of commodity being shipped. In an analysis of the links between freight transport and production, import and export data between 1981 and 1992, Fosgerau and Kveiborg (2004) showed that predicting freight transport from aggregate production values would have led to overestimation of transport growth due to the economic shift to less transport intensive industries.

In developed economies, disaggregated freight-flow analysis is typically enabled through commodity flow surveys (CFSs). The most well-known and detailed survey-based national freight demand models are SAMGODS (the Swedish model) and the Norwegian model. The discrete choice models for mode and shipment size choice that are being developed for the European model "Tools for Transport Forecasting and Scenario Testing (TRANS-TOOLS)" use CFSs from Sweden and France as databases for freight flow estimation (De Jong et al., 2016). The United States CFS has been conducted every 5 years since 1993; the latest data is for 2017 (United States Bureau of Transportation Statistics, 2021). The resource-, execution- and subsequent analytical capacity required to conduct regular CFSs, and transform these into freight demand models, are however not available in emerging economies.

The conundrum is that, in emerging economies, where information on freight flows and logistics costs is needed the most due to relatively higher levels of investment required, and where new policies need to be formulated, freight-flow information is scarce and difficult to develop (Figure 1). Furthermore, the relative impact of freight logistics investments in emerging economies is much higher than in the developed world (due to inter alia investment backlogs), exactly where information to guide these investments is usually not well developed. As economies mature and investments yield results, the relative improvement (or impact) of freight logistics investments taper off (refer Figure 2) (Havenga et al., 2020).

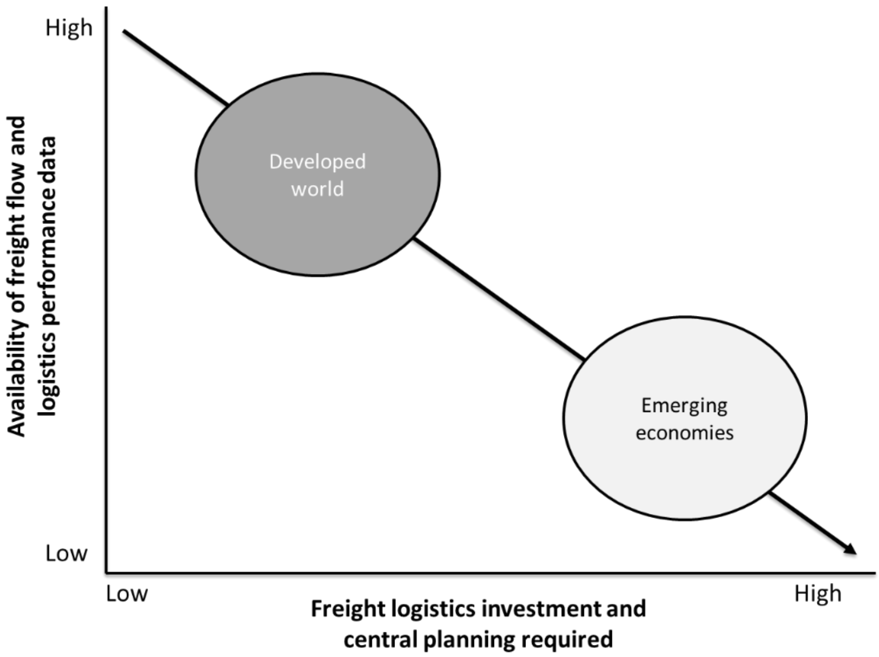


**Figure 1: Asymmetry between logistics information availability and logistics information need in developed and emerging economies (Havenga et al., 2020)**

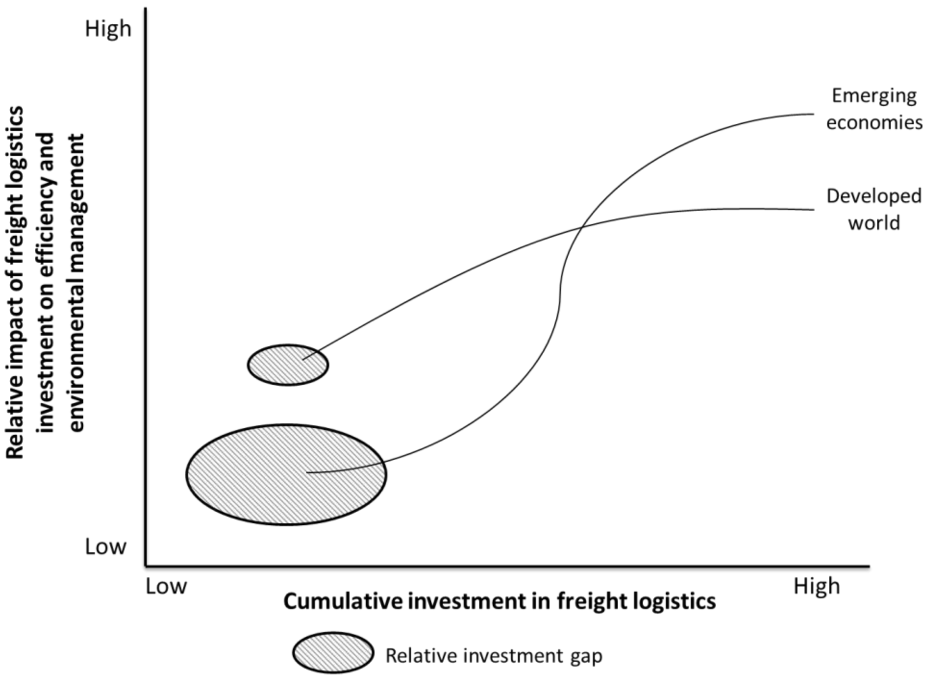


**Figure 2: Asymmetry between impact and required investments in developed countries and emerging economies (Havenga et al., 2020)**

The candidate's contribution is specifically in the development of a practical macrologistics instrumentation construct for emerging economies, i.e. the quantification of commodity-level, spatially-disaggregated freight-flow models *based on data available in the local economy*, what will be referred to as disaggregated national freight demand models (DNFDMs). These models are already a key input to informing targeted lowest cost of logistics configurations for the emerging economies that are discussed in this dissertation.

In the remainder of this chapter, the research framework is delineated, and the research approach and structure of the dissertation are discussed.

## 1.2 Research framework

### 1.2.1 Research problem

Logistics efficiency is increased through targeted interventions, which in turn support national socio-economic objectives. In order to identify and prioritise these interventions, an understanding of the sectoral and geographical composition of freight demand is required, within the context of total national freight flows. In developed economies this understanding is typically enabled by integrating the outputs of commodity flow surveys with a variety of other sources (such as international trade and industry data). The resource-, execution- and subsequent analytical capacity required to conduct regular CFSs, and transform these into freight demand models, are however not available in emerging economies.

The ***research problem*** addressed in this dissertation is that there is currently not a viable approach to develop, apply and update DNFDMs in emerging economies due to the absence of formal comprehensive disaggregated statistics on the freight transport market, as well as the absence of regular CFSs.

### 1.2.2 Research aim and objectives

The ***primary aim*** of this research is to:

> Develop a methodology for modelling sectorally and regionally disaggregated freight flows in emerging economies in the absence of formal interrogable statistics on the freight transport market by leveraging existing data sources and successfully applying the outputs to inform macrologistics decision-making.

A resulting **secondary aim** is to:

> Contribute to the body of knowledge in the developing field of macrologistics in general, and specifically how it relates to emerging economies.

The research aims are supported by ***research objectives (ROs)*** as outlined in Table 1:

**Table 1: Research objectives and related chapters**

| Research objectives (ROs) | Chapter |
|---|---|
| RO1. Establishing the rationale for an explicit focus on macrologistics | 1,2 |
| RO2. Developing a methodology for the development of DNFDMs in emerging economies | 2 |
| RO2.1. Identifying existing data sources typically available in emerging economies | 2 |
| RO3. Illustrating the utility of the outputs from the DNFDMs through application in: | |
| RO3.1. Data-driven macrologistics policy formulation and investment prioritisation in support of macroeconomic goals | 3 |
| RO3.2. Re-imagining macrologistics value chain development | 4 |

The results from the DNFDMs of four emerging economies, namely South Africa, India, Uzbekistan and Mongolia will be used as proof-of-concept to reach these objectives.

### 1.2.3 Research delimitation

The research focuses on developing an understanding of the competitive national freight transport market to inform *inter alia* macrologistics policies and infrastructure investment decisions. The following is therefore excluded:

- An analysis of ring-fenced freight flows related to pipelines, conveyor belts, ring-fenced bulk (rail-only) flows, and air transport (due to the nature of national freight-flow modelling, all these volumes are included in the totals, but they will not be analysed in detail due to their unique, ring-fenced nature);
- The conversion of flows to vehicle-units and assigning these flow to networks;
- Metropolitan freight flows;
- Passenger transport; and
- The estimation of logistics costs based on the freight flows.

These exclusions can be done, and the candidate has, in isolated cases, been involved to implement these for some of the countries, but it is deemed outside the scope of this dissertation.

The DNFDMs will be developed and validated for four emerging economies, namely South Africa, India, Uzbekistan and Mongolia. While the general principles are transferrable to other emerging economies, the specific characteristics of each country's freight transport industry, and the available data sources, will inform each specific application.

## 1.3 Research approach

In line with the primary research aim, the research is an empirical study, utilising secondary quantitative data analysis (refer Figure 3).

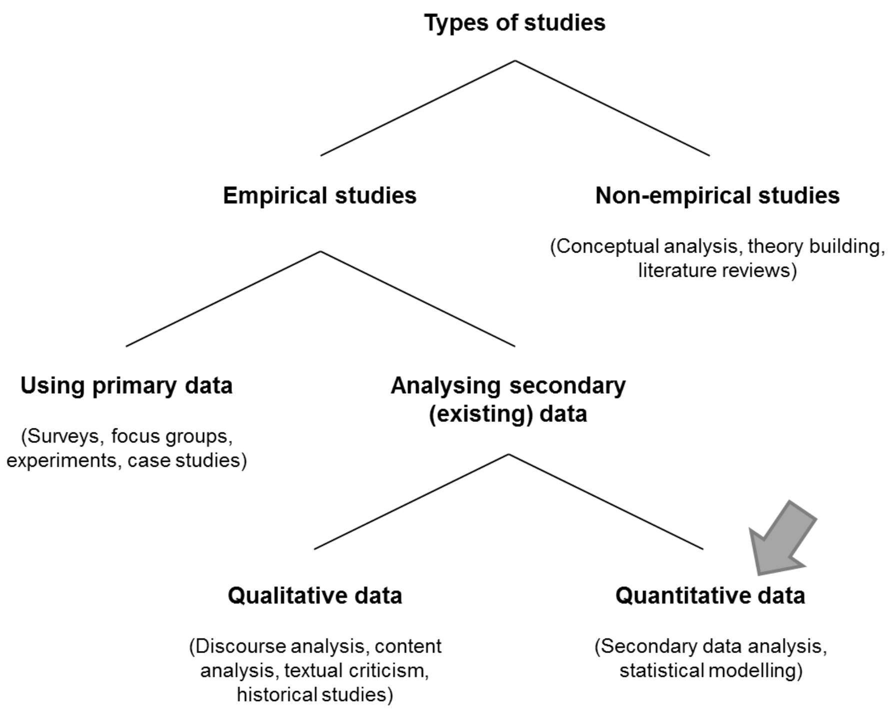


**Figure 3: A typology of research design types (Mouton, 2013)**

Transport demand modelling was formalised for passenger transport planning during the 1960s with the development of the sequential four-step model, namely trip generation, trip distribution, mode choice and route assignment (De Jong et al., 2004). The exponential increase in international trade since the 1960s, due to *inter alia* technological advancements (such as the standard shipping container and the rapid development of information technologies), supported by regulatory changes (notably transport deregulation, trade liberalisation and increased capital mobility) (Grant et al., 2013; Van den Berg and Lewer, 2007), necessitated the development of increasingly detailed freight-flow models, informed by the generic four-step approach (De Jong et al., 2004). However, as highlighted in Section 1.1, the lack of data in emerging economies necessitated a creative approach to realising this sequential approach in emerging economies. The principles of grounded theory provided this inspiration for the approach to secondary data analysis and modelling that enabled the development of the DNFDM research methodology as presented in Chapter 2. The grounded theory principles are utilised in the development of the geographically and commodity-level disaggregated supply and demand matrices (Step 1 of the sequential four-step transport modelling approach), and for the development of the variables used as inputs to model the distribution of freight flows (Step 2 of the sequential four-step transport modelling approach)[1]. This is discussed in detail in the published work in Chapter 2.

[1] The modal split component (Step 3) is not required for modelling the status quo (yet) as rail transport data has been available for all countries where the freight flows have been estimated – the modelling of distribution is therefore for road freight flows only. Modal split becomes important when forecasting freight flows, which is an important next step.

Grounded theory is the discovery of theory from data which is systematically obtained and analysed, for the purposes of improved practical understanding, analysis and prediction, and for advancing theory without preconceived outcomes or *a priori* assumptions. The key principles of grounded theory that informed the research approach in this dissertation are a general method of comparative analysis, i.e. systematic and simultaneous collection, coding and analysis of a variety of data sources, reinforced by theoretical sampling. The latter refers to the process of collecting data for comparative analysis in order to generate theory that is integrated, close to the data, and expressed in a form clear enough for further testing. The notion of theory generation as 'process' requires that all three operations (collection, coding and analysis) be continuously intertwined. This is an iterative process until theoretical saturation is reached, guided by theoretical sensitivity (discussed in further detail below (Glaser and Strauss, 1967: 43).

Grounded theory research is regarded as 'rich and robust' due to its application possibilities in areas where the relevance of established theories is questioned, and where official data is either scarce or not well-coded nor easily accessible (Anjoga et al., 2016).

The discovery of the research methodology for DNFDM in emerging economies was inspired by the grounded theory principles as follows (refer Figure 4):

1. **Data discovery and comparative analysis:** The systematic discovery, collection, coding and analysis of data from various sources and, through data triangulation and stakeholder engagement, establishing specific data points. The need for further verification and additional data requirements arise where there are significant, unexplained discrepancies between sources. Using a variety of sources reduces these inaccuracies and increases confidence in the research outputs. This is an iterative, cyclical process until data saturation is obtained (see paragraph number 3 on data saturation below).

   This comparative analysis process is also referred to as data triangulation i.e. the use of data from different sources to overcome the challenge of incomplete or conflicting datasets, to deepen understanding of the sector, and to cross-validate which increases the credibility of outputs (Mangan et al., 2004; Rahman, et al., 2017). The important principles of data triangulation are that known data points can be utilised to estimate unknown data points, that estimates can be improved by utilising more data inputs, and that this iterative process can eventually lead to a reliable description of the whole landscape under investigation if done diligently.

   In the context of this dissertation, the direct output of the data discovery and comparative analysis process is to firstly, define the level of commodity and regional disaggregation pragmatically possible in each economy, and then develop a set of regional supply and demand table matrices for each commodity. The various commodity supply and demand tables are interdependent and supply of a specific commodity from a region demanded in another region is determined either by the intermediate demand for that commodity in a downstream manufacturing process or final demand, increasing the importance of the process of iterative comparative analysis.

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The assignment (Step 4) of flows to vehicle-units and networks falls outside the scope of this dissertation. The latter is being investigated and an exploratory study has already been conducted in Kolkata (refer Section 5.3)

2. **Pareto-based or targeted sampling.** In the grounded theory literature this principle is referred to as 'theoretical sampling', i.e. in the process of data collection, coding and analysis, the researcher decides which data to collect next and where to source it, in order to improve cross-validation and convergence. This process of data collection is controlled by the emerging theory and not based on a preconceived theoretical framework (Glaser and Strauss, 1967).

   In the context of this dissertation the decision of which data to collect next is informed by the data triangulation process (described in paragraph number 1 above). Priorities for questionable or outstanding data are informed by the Pareto contribution of industries and regions in terms of value and volumes; deep-dives are conducted to enrich data through targeted interactions with industry or freight role players, and engagement with data custodians to unlock access to richer, more detailed data for coding. Where it emerges that data is not available on the disaggregated level required, proxies are identified and populated to facilitate credible disaggregation of aggregate economic data. This, in turn, iteratively informs the interactions between regional supply and demand for the commodities under question, as will be explained in Chapter 2.

3. **Data saturation.** In grounded theory, theoretical saturation is referred to as "the criterion for judging when to stop theoretical sampling … saturation means that no additional data are being found whereby the [researcher] can develop properties of the category … the researcher becomes empirically confident that a category is saturated" (Glaser and Strauss, 1967: 61). The iterative process of data collection, coding, analysis and sampling provides a proportioned view of the data and discrepancies tend to be reconciled, improving confidence in the inputs and robustness of the outputs (Glaser and Strauss, 1967: 68). Data saturation is reliant on the iterative process of data collection, coding, and analysis reaching a state of completeness within and across contexts (O'Reilly et al., 2012).

   The sampling, coding and comparative analysis method is conducted in each economy until a set of supply and demand matrices for the national economy has been developed that aligns with available economic aggregates – e.g. production figures of major industries, major freight flows, cross border and international trade data, customs data and truck counts.

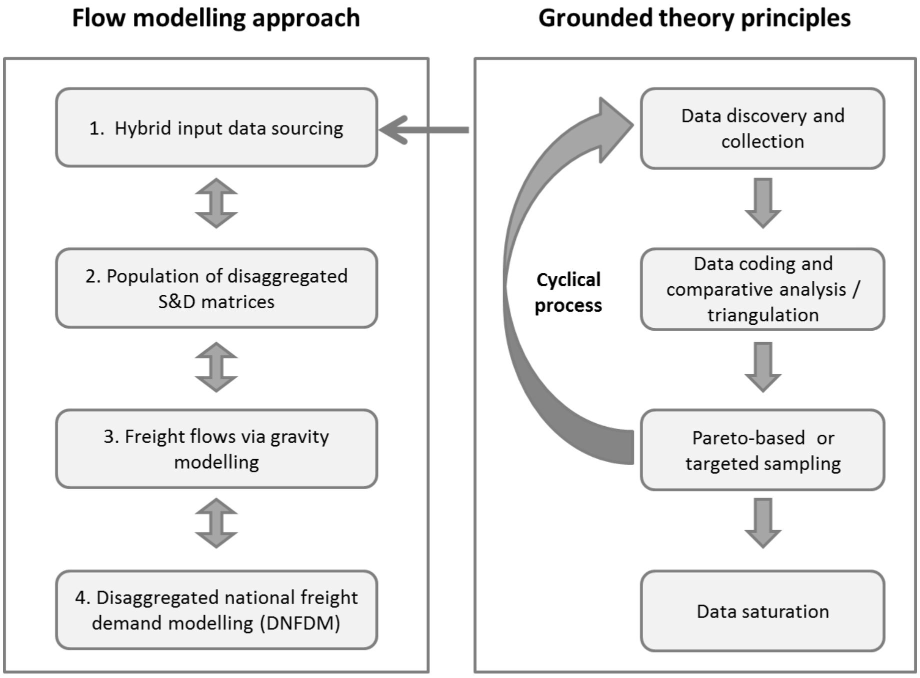


**Figure 4: Research approach for enabling the development of the DNFDM methodology**

An important consideration is theoretical sensitivity or, for the purposes of this dissertation, context sensitivity. As acknowledged by the founders of grounded theory, more than five decades ago, “the [researcher] should also be sufficiently theoretically sensitive … which involves the [researcher's] ability to have theoretical insight into his area of research, combined with an ability to make something of his insights” (Glaser and Strauss, 1967: 46). For the purposes of the work described in this dissertation, this is enabled by the collaborative (with stakeholders) scoping, development and interpretation of DNFDMs to address the specific needs, and take cognisance of existing policies, of the country in question. It also refers to the close working relationship between the researcher (the candidate and his colleagues), project sponsors, and freight data custodians to obtain access to existing data. The process of identifying and empowering ‘macrologistics modellers’ is an important endeavour and will gain traction, akin to the process of elevating the supply chain function to the top management and decision-making echelons in organisations. Outside of specific projects, regular engagement with freight flow professionals through conferences and peer-reviewed publications create opportunities to soundboard the development of the methodology.

This process of constant comparative analysis and targeted sampling until data saturation is reached, is aligned with guidelines developed by the Federal Highway Administration (United States Department of Transportation) (2019) on data collection, compilation and refinement to support freight planning and forecasting to fill gaps in existing data sources namely (1) identify and assess available data sources and identify gaps; (2) collect, refine and clean existing data to create a base dataset of existing freight data; (3) collaborate with freight stakeholders to collect or estimate identified gaps; (4) process and combine existing and new data to create an integrated freight database; (5) create a process to maintain and update the freight database.

The methodology was developed and refined through applying the grounded theory principles during the development of freight flow models for four emerging economies:

1. South Africa, one of the two biggest economies in Africa, with a far more developed services sector than most emerging economies and often seen as a “mixed” economy in terms of development;
2. India, as one of the largest and fastest growing emerging economies with very significant infrastructure programs;
3. Uzbekistan, a prior Soviet economy, in the process of political and economic transition from authoritarian rule since 2016, one of only two double landlocked countries in the world with a potential strategic role in Central Asia;
4. Mongolia, which is also landlocked but neighboured by two giants, i.e. Russia and China, and is also on one of the three alternative corridors of the Belt and Road initiative.

## 1.4 Structure of the dissertation

This dissertation is structured as follows:

Chapter 1: The need for freight demand modelling in information-scarce environments is discussed to provide the rationale for the dissertation’s research aims and objectives. Subsequently, the research approach to achieve the research objectives is outlined.

Chapter 2: The freight demand modelling methodology derived from the grounded theory approach outlined in Chapter 1 is documented and discussed based on a published article and a published book chapter, both peer-reviewed.

Chapter 3: The derived methodology is successfully applied to develop flow models in emerging economies which can contribute to the solving of macrologistics problems, and discussed based on a peer-reviewed published book chapter (covering South Africa and India) and an unpublished, submitted article (covering Uzbekistan).

Chapter 4: The way in which the DNFDM outputs can be used to develop industry-level value chain solutions and inform shared value chain technologies for economic development is discussed (applied in Mongolia and South Africa), based on two unpublished articles, one submitted and one ready for submission.

Chapter 5: The concluding chapter includes a summary of the research, a discussion of the candidate’s unique contributions and potential areas for future research.

Each article and book chapter that is included in this dissertation, appears in its original formatting (which includes their own page numbers in their original source, and should not be confused with the page numbering of this dissertation). The pages of the articles and book chapters included in this dissertation are indicated with a black border frame to easier identify included material.

# Chapter 2. Methodology for developing disaggregated national freight demand models in emerging economies

This chapter addresses the following research objectives:

RO2: Developing a methodology for the development of DNFDMs in emerging economies

RO2.1: Identifying existing data sources typically available in emerging economies

This chapter consists of four sections. Section 2.1 positions the chapter within the narrative of the dissertation. Sections 2.2 and 2.3 contain the published article (covering South Africa) and published book chapter (covering South Africa and India) respectively, which comprise the primary part of this chapter, and discuss the iterative process that resulted in the DNFDM methodology. Finally, Section 2.4 is a combined summary of the two publications.

## 2.1 Introduction

The published article and book chapter presented in this chapter describe the process to develop a methodology for DNFDMs for emerging economies based on the application of grounded theory principles. (The publications also support RO1: Establishing the rationale for an explicit focus on macrologistics and RO3.1: Data-driven macrologistics policy formulation and investment prioritisation in support of macroeconomic goals. In the interest of a cohesive dissertation narrative, the salient points supporting RO1 is addressed in Chapter 1, Section 1.1, while RO3.1 is addressed in Chapter 3). In support of the discovery of the DNFDM methodology, it is of relevance to mention that the candidate was also involved in developing DNFDMs for the sub-Saharan African region (King et al., 2016) and the Western Cape province in South Africa (Western Cape Government, 2019). These research projects supported the refinement of the methodology and validated the approach for transnational groupings (sub-Saharan Africa), as well as more granular research within national boundaries (Western Cape province). (These publications are not included in the dissertation due to being published or commenced prior to the candidate's registration).

The main objective of the published article in Section 2.2. is to contextualise freight flow instrumentation in the emerging macrologistics discipline, and the potential relationship with macroeconomic goals. This understanding is very important, both as a foundation for the successful development of DNFDMs in emerging economies, and to support the *raison d'etre* of macrologistics namely to lower total macroeconomic cost of ownership, in the same vein as costing and optimising business or industry level logistics inform micrologistics cost of ownership decisions. An overview of the DNFDM methodology for South Africa is provided, identifying and discussing the building blocks of macrologistics instrumentation, including the main data sources available, a high-level explanation of the use of hybrid data to reduce the modelled component of supply and demand, as well as the inputs into the distribution (flow) model (Steps 1 and 2 of the generic four-step flow modelling approach discussed in Section 1.3). These processes are discussed in more detail in Section 2.3.[2]

[2] This article also provides an outline of South Africa's logistics cost model. This is a crucial next step of macrologistics instrumentation and is especially useful if the costing is based on the detailed flows from DNFDMs. The complete disaggregated logistics cost model has however not yet been applied in the other geographies discussed in this

The published book chapter in Section 2.3 discusses South Africa's DNFDM methodology in more detail and expands the application of the methodology to another major emerging economy, namely India. Given the experience gained in a second geography, it was possible to develop more clarity on typical challenges hindering freight demand modelling in emerging economies, as well as the salient contributions of the DNFDM methodology. The discussion on hybrid input data sourcing, apportionment, data triangulation and the final model outline is also much richer, highlighting the depth gained in the methodological development and application in a second geography, a major geography with significant socioeconomic challenges and a large initial reluctance to share data. A summary of the standardised outputs of the DNFMSs are provided, facilitating model development (as the envisioned end-state is known) and comparisons between emerging economies. A further methodological addition in the second article is the discussion on macrologistics market segmentation – i.e. the link between freight flows and the basic economic value chain, and what this means for macrologistics service provision. On a macrologistics level, market segmentation is as important as on a business level as it will inform the strategic priorities of a nation's macrologistics response, as shown in Chapter 3. The spatial and sectoral quantification of all freight transport market segments in the economy means the market spaces can be accurately identified, and infrastructure investments and service delivery can be more accurately costed, targeted, and aligned with national infrastructure master planning.

For each of the publications, the candidate was responsible and deeply involved in the cyclical process of grounded theory (refer Figure 4 in Section 1.3), i.e. the discovery, collection, coding, analysis, triangulation, and targeted sampling to reach data saturation for the core building blocks of the DNFDM, namely supply and demand data, the road networks and decay factors required for flow modelling, as well as the flow outputs. This hands-on, iterative process led to the refinement of the methodology and a deep understanding of its execution in emerging economies.

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dissertation, and is included in suggestions for future research (high-level estimates of logistics costs with a link to DNFDMs have been completed and will be mentioned where relevant). A detailed analysis of the logistics costs model however falls outside the aim of this dissertation.

## 2.2 Published article: "Macrologistics instrumentation: Integrated national freight-flow and logistics cost measurement"

The article presented in this section is the published version of a peer-reviewed article published in the journal 'Transport Policy', the official journal of the World Conference on Transport Research Society[3]. This is an international refereed journal aimed at improving quality of transport policy and strategy analysis, bridging the gap between theory and practice in transport.

One of the stated requirements of the journal is that articles are expected to have clear policy and strategy relevance. Publication therefore supported this dissertation's intended contribution of supporting macrologistics decision-making in emerging economies and, as a result, supporting the development of the macrologistics body of knowledge. The article is available at https://doi.org/10.1016/j.tranpol.2019.10.014) (not open access).

[3] This article was co-authored by Havenga J.H., Witthöft, I.E. and Simpson, Z.P (2019). The formal declaration of author contributions, as required for publications included in dissertations by Stellenbosch University, is provided in Appendix A.

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## 2.3 Published book chapter: "A methodology for disaggregated freight demand modelling in emerging economies"

The candidate and his research collaborators were requested to contribute two chapters towards an introductory book on freight demand modelling in emerging economies due to the work done on freight demand modelling in South Africa and India[4]. The book, 'Freight Transport Modeling in Emerging Countries', published in 2020, is an initiative of the Special Interest Group on Freight Transport Modelling of the World Conference on Transport Research Society, edited by Ioanna Kourounioti, Lóránt Tavasszy and Hanno Friedrich, who are leading researchers in the field of freight transport modelling. The publication showcases alternative data collection methods and evaluation techniques, as well as successful applications of resulting freight transport modelling outputs in emerging economies (including South Africa, India, Turkey, Chile and Greece).

The intent of the book is to support the broader application of these approaches in emerging economy macrologistics decision-making, including the direction of large-scale infrastructure investment budgets towards those logistics investments that will facilitate sustainable growth in the domestic economy, as well as support targeted participation in global trade. In order to support these ambitious goals, sufficiently detailed freight-flow intelligence is required. In the first contributed chapter – which is titled as Chapter 4 in its original published formatting, the DNFDM methodology that enables this detailed intelligence is described. (The second contributed chapter details the model outputs and is discussed in Section 3.2 – which is titled as Chapter 8 in its original published formatting). The work integrates and expands on the research and publications by the candidate and his co-authors over the past decade.

The book is aimed at policy-makers to inspire the pursuit of data-driven decision-making approaches; and at scholars and researchers to showcase the opportunities for enabling such approaches in data-scarce environments.

The book is available for purchase from https://www.sciencedirect.com/book/9780128212684/freight-transport-modeling-in-emerging-countries.

[4] The book chapters were co-authored by Simpson, Z.P, Havenga, J.H., Witthöft, I.E. and Aritua, B (2020a). The formal declaration of author contributions, as required for publications included in dissertations by Stellenbosch University, is provided in Appendix A.

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## 2.4 Summary: Methodology for developing disaggregated national freight demand models in emerging economies

The publications included in this chapter succeeded in meeting the following research objectives:

RO2: Developing a methodology for the development of DNFDMs in emerging economies

RO2.1: Identifying existing data sources typically available in emerging economies

(As mentioned in the introductory section to this chapter, the publications also support RO1: Establishing the rationale for an explicit focus on macrologistics and RO3.1: Data-driven macrologistics policy formulation and investment prioritisation in support of macroeconomic goals. In the interest of a cohesive dissertation narrative, the salient points supporting RO1 is addressed in Chapter 1, Section 1.1, while RO3.1 is addressed comprehensively in Chapter 3).

The challenges hindering freight demand modelling in emerging economies can be summarised as unusable aggregate data exacerbated by a silo approach to logistics, inappropriate modelling techniques which disregard local context and limited funding resulting in a lack of a cohesive macrologistics intelligence approach. The work on the DNFDM supports addressing these challenges through:

- Highlighting the possibilities that can be unlocked through capturing and coding detailed data into a usable format which feed into macrologistics decision-making models;
- Working with existing data sources and data custodians to leverage resources already deployed;
- Utilising the limited funding to build sufficient datasets and linkages between datasets to improve and sustain future modelling efforts.

The publications included in this chapter described the volumetric instrumentation of macrologistics through the development of the DNFDMs. The instrumentation is premised on demand-side modelling – i.e. it models the demand for freight flow provision created by the time and place disparity between supply and demand interactions. A systemic analysis is enabled by commodity-level, spatially disaggregated supply and demand matrices, verified against known economic aggregates. The volumetric outputs from the supply and demand matrices are then transformed into freight flows via a gravity model – the volumetric link ensures both internal alignment between these models and flow-level alignment with national aggregates.

Seminal work on gravity modeling was done by Chrisholm and O'Sullivan (1973) on freight flow modelling in Great Britain. They considered attempts to model the distribution of traffic between the 78 zones distinguished in their survey data, using both gravity model and linear programming approaches. In similar research, Pifield (1978) found the performance of a gravity model proved to be more successful than linear programming.

In the case of South Africa, the first models utilised the macroeconomic Input-Output (I-O) table of the economy as a starting point to populate spatially and sectorally disaggregated supply and demand matrices. I-O tables are however published in monetary terms and not spatially disaggregated, necessitating significant work to convert to volumes and disaggregate. Once a base had been established, the use of actual data gained prominence due to improved accuracy for volumetric modelling, verified against macroeconomic aggregates, including checking for shifts in I-O coefficients when updated I-O tables become available. In many other emerging economies, such as those covered in this dissertation (India, Uzbekistan and Mongolia) detailed updated I-O tables were not available. The starting point is therefore to determine the level of regional and commodity disaggregation possible in each economy through data discovery, and then populate supply and demand tables based on actual data as far as possible. The published book chapter in Section 2.3 demonstrates the depth gained in the methodological development and application in a second geography

(India), a major geography with significant socioeconomic challenges and a large initial reluctance to share data. This extension was therefore regarded as a very successful proof-of-concept for the approach.

The novelty of the methodology is that a standardised construct has been developed that targets the use of available statistics in emerging economies (where comprehensive CFSs are not available) to populate regionally and sectorally disaggregated supply and demand tables for the economy under question. Available statistics refer inter alia to sectoral production and consumption data, import and export value and volume per commodity per port and/or border post, rail and waterway value and volumes (where applicable), container content data from ports or major shipping lines, and road freight traffic counts, available from rail and port operators, government departments, national statistics offices and industry associations. All source data are coded to align with the predefined commodity groups as a critical step to improve model accuracy, enabling valid comparisons and cross-validation between different sources, facilitating integration of data from various sources and increasing accuracy of freight flows estimates. This is supplemented by established apportionment approaches to fill data gaps using proxies such as employment, population and income, while controlling against known sectoral and regional aggregates. Table 4.1 in the published book chapter in Section 2.3 provides detail of the sources of actual volumetric data sourced, codified and analysed to populate disaggregated supply and demand tables which serves both as a confirmation of the breadth of data available as well as a starting point for other researchers.

While the level of disaggregation seems onerous (for South Africa, 369 geographical areas and 83 commodities; for India, 672 geographical areas and 31 commodities), logic prevails through applying the Pareto principle in research effort – twenty commodities contribute 80% of South Africa's general freight tonnes (excluding known flows of export coal and export iron ore) while 12 commodities contribute 80% of India's total tonnes – although sufficient effort must be extended to understand high value commodity flows. The Pareto contributions are also discovered through the cyclical process depicted in Figure 4, gradually narrowing down the data requirements and reducing the need for targeted sampling. This granular iterative hybrid modelling approach (or cyclical process) therefore eventually leads to 'data saturation' (sufficiently detailed data that is consistent with available aggregates and the economy's basic structure), which increases confidence in both the data inputs and outputs – the inputs are transparent and both the actual data and modelled components are interrogable. It also creates an appreciation of the intrinsic value of such information with stakeholders, which not only increases access to data, improving the model outputs, but also empowers stakeholders in emerging economies to maintain the DNFDMs going forward.

This cyclical process is conducted both in terms of the population of the spatial supply and demand matrices per commodity, as well as the development of the distance decay parameters for each commodity or groups of commodities, the key inputs into the spatial planning software that models the interaction between supply and demand using a gravity model, calibrated with known modal flows (such as rail) and known industry flows (based on an understanding of the location of major primary and secondary sector activities, and the value chains involved). As with the supply and demand matrices, the objective was to populate flows between districts with actual data as far as possible. Correlation with the national aggregates ensures that traffic volumes are not over- or under-reported.

The inputs for the supply and demand tables are therefore dynamic and will change from economy to economy, depending on data sources. Yet, the DNFDMs render standardised output formats that are comparable across countries, even if improved or continuously updated, irrespective of various data inputs. These standard outputs are geographically and sectorally disaggregated supply and demand data, and resulting freight flows with the primary parameters of origin, destination, commodity, volume of freight and transport mode.

The specific contributions of this modelling approach are that a complete view of economic activity (supply and demand) is developed on the most detailed geographical and sub-sectoral / commodity level that is available in the economy under question. Freight flows are then derived from this complete view of economic activity, resulting in useful, practical outputs that can be segmented according to various geographical and commodity combinations to inform specific macrologistics questions (refer Chapter 3). The strength is in the *disaggregated* analysis made possible, which despite the onerous data requirements, remains a cost-effective approach for the level of detail rendered and the resources required compared to primary research which can only yield similar comprehensiveness and validity with very large samples.

A further methodological contribution in the published book chapter is the discussion on macrologistics market segmentation, i.e. the link between freight flows and the basic economic value chain, and what this means for macrologistics service provision. The output is the classification of freight into logistically sensible segments for the purposes of policy and investment prioritisation, while also providing a simplified view of a nation's macrologistics strategy – this is especially beneficial in economies where such a snapshot has not been available before – it directs a country's focus, provides a clear indication of the match between current logistics infrastructure and freight flow demand, thereby enabling prioritisation of logistics infrastructure investments. On a macrologistics level, market segmentation is as important as on a business level as it will inform the strategic priorities of a nation's macrologistics response.

The outputs of these models aid macrologistics decision-making through data-driven policy discussions and infrastructure investment planning which, in turn, support the attainment of national socio-economic goals. This is discussed in Chapter 3.

# Chapter 3. Applying DNFDM outputs: Data-driven macrologistics policy formulation and investment prioritisation in support of macroeconomic goals

This chapter addresses the following research objective:

RO3: Illustrating the utility of the outputs from the DNFDMs through application in:

RO3.1: Data-driven macrologistics policy formulation and investment prioritisation in support of macroeconomic goals

This chapter consists of four sections. Section 3.1 positions the chapter within the narrative of the dissertation. Sections 3.2 and 3.3 contain a peer-reviewed published book chapter (covering South Africa and India) and a submitted article (covering Uzbekistan) respectively, which comprise the primary part of this chapter, and discuss the application of DNFDM outputs to enable data-driven macrologistics policy formulation and investment prioritisation in support of macroeconomic goals. Finally, Section 3.4 is a combined summary of the two publications, highlighting the macrologistics priorities for each country that could be determined due to the availability of DNFDMs.

## 3.1 Introduction

The published book chapter (covering South Africa and India) and submitted article (covering Uzbekistan) included in this chapter describe the application of the DNFDM outputs to inform data-driven macrologistics policy development and freight infrastructure investments. The publications demonstrate that country-level freight flow measurements based on the methodology is possible for a range of countries on the one hand and, on the other hand, robust analysis of the modelling outputs illustrates the usefulness of disaggregated freight flow measurement to address complex macrologistics problems.

The published book chapter in Section 3.2 focuses on application outputs for South Africa and India. It demonstrates that a concise macrologistics narrative can be developed for emerging economies based on the applied instrumentation, including an analysis of aggregate, sectoral and modal freight flows; transport market segments and resulting overarching logistics requirements; and an evaluation of modal shift opportunities to optimise the strengths of road and rail transport and address cost, congestion and economic development challenges. For both South Africa and India, data-driven macrologistics priorities are identified.

The submitted article in Section 3.3 provides detail on the development of Uzbekistan's DNFDM (referred to as the Uzbekistan Freight-Flow Model – UFFM). The same methodology is applied as described in Chapter 2, with a larger focus on describing the cyclical process of data triangulation due to the limited input data available in Uzbekistan. A comparison between UFFM outputs and available freight-flow data in Uzbekistan is also provided to highlight how comparison with economic aggregates and key transport indicators can inform data triangulation and validity of outputs. High-level logistics costs were also calculated. In terms of output, a macrologistics narrative is developed for Uzbekistan to enable the positioning of the transport and logistics industry in the country's New Development Strategy. Domestic and regional opportunities for improvement are also identified.

The candidate was responsible for the development of the South African, Indian and Uzbekistan DNFDMs discussed in the chapter, as well as the collaborative interrogation of the outputs to provide the analyses presented.

## 3.2 Published book chapter: "Spatially and commodity-level disaggregated freight demand modelling in emerging economies: Applications for South Africa and India"

As discussed in Section 2.3, the candidate and his research collaborators were requested to contribute two chapters towards an introductory book on freight demand modelling in emerging economies due to the work done on freight demand modelling in South Africa and India[5]. In the second chapter included here, the outputs of disaggregated national freight demand models are applied to enable targeted policy development and large-scale collaborative infrastructure investment planning. In both case-study countries (South Africa and India) a virtuous cycle emerged – high-level quantification is developed with little data to inform responses to pressing questions in the logistics landscape. This leads to buy-in and increased participation by users enabling the provision of more data and the quantification of more pertinent questions and scenarios to facilitate decision-making.

The level of disaggregation (1) supports mesoscopic decision-making to inform spatial, sectoral and modal optimisation and (2) leads to high confidence levels in the aggregated freight flow outputs from the models which enable planners to identify and address gaps in national freight transport and logistics policies and infrastructure investments.

(The first contributed chapter is discussed in Section 2.3 in the dissertation – which is titled as Chapter 4 in its original published formatting, presented in this section). The work integrates and expands on the research and publications by the candidate and his co-authors[6].

The book is aimed at policy-makers to inspire the pursuit of data-driven decision-making approaches; and at scholars and researchers to showcase the opportunities for enabling such approaches in data-scarce environments.

The book is available for purchase from https://www.sciencedirect.com/book/9780128212684/freight-transport-modeling-in-emerging-countries.

[5] The book chapters were co-authored by Simpson, Z.P., Havenga, J.H., Witthöft, I.E. and Aritua, B (2020b). The formal declaration of author contributions, as required for publications included in dissertations by Stellenbosch University, is provided in Appendix A.

[6] The candidate formed part of a core research team to develop India's first DNFDM, sponsored and project managed by the World Bank. The candidate co-authored a World Bank working paper on this project, "Unlocking India's Logistics Potential : The Value of Disaggregated Macroscopic Freight Flow Analysis" (Aritua et al., 2018). A paper on India's DNFDM – "Developing a disaggregated national freight flow model for India" – was also presented by the candidate at the World Conference on Transport Research in Mumbai during 2019 (Aritua et al., 2019). The section on India in the book chapter was based on these publications.

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## 3.3 Submitted article: "Informing macrologistics connectivity in emerging economies through a triangulated research approach – The case of Uzbekistan"

The article presented in this section is an unpublished article that has been submitted in May 2021 to the journal 'Case Studies on Transport Policy" and is awaiting reviews. This journal is specifically suited to case studies and is the sister journal to the journal 'Transport Policy', which is the official journal of the World Conference on Transport Research Society. This is an international refereed journal aimed at improving quality of transport policy and strategy analysis, bridging the gap between theory and practice in transport. The article is therefore deemed a good fit as it provides inputs into the contribution of the country's transport and logistics strategy to Uzbekistan's New Development Strategy. The candidate formed part of a core research team to develop a policy paper, sponsored and project managed by the World Bank, to underpin the Strategy for the Development of the Transport System of the Government of Uzbekistan (World Bank, 2019). The candidate provided input to the policy paper, and expanded on this contribution for article publication.

# Informing macrologistics connectivity in emerging economies through a triangulated research approach: The case of Uzbekistan

Abstract

Uzbekistan has the potential to become a regional hub linking Southeast Asia, South Asia, the Commonwealth of Independent States, and Europe. In order to inform the implementation of Uzbekistan's Strategy for the Development of the Transport System, a triangulated research approach was followed to develop a spatially and commodity-level freight-flow model for the country. The model outputs highlight that freight-flow distribution is heavily skewed towards the East, that the country has significant exposure to freight risks beyond the borders due to the inordinate long distances of cross-border flows, and that demand for transport, and logistics costs, are high relative to GDP. Transport policy, infrastructure development and the role of transport and logistics in development planning should therefore be prioritised as a strategic input into economic growth and development success, including the intelligence that enables these activities. There seems to be opportunities for domestic and regional consolidation, which can lead to the improved use of rail and intermodal solutions, and support the development of effective Special Economic Zones. These outputs can be refined with access to more detailed data.

**Keywords:** Data paucity, data triangulation, emerging economies, freight flows, macrologistics, Uzbekistan

## 1 Introduction

Uzbekistan is Central Asia's most populous country, with its 32 million citizens representing nearly half the region's total population. Tashkent, the capital, is Central Asia's biggest city. The government is exploring various initiatives for enhancing regional integration and connectivity, diversifying trade routes in the context of China's Belt and Road Initiative (BRI), and exploring maritime access options. The country has the potential to become a regional hub linking Southeast Asia, South Asia, the Commonwealth of Independent States, and Europe (World Bank, 2020), where logistics and especially logistics facilities can play a key role in the region, similar to Singapore's successful positioning as a hub for Southeast Asia (Yue and Lim, 2003).

Uzbekistan's economic development goal is to move from a centrally-planned, inward-oriented economy towards a more open, integrated, value-adding and export-driven economy (Tsereteli, 2018) supported through reforms to further improve the investment climate, the efficiency of public sector investments, and service delivery mechanisms in various sectors of the economy. The country has a number of strengths to leverage. Uzbekistan is the world's seventh largest producer and fifth largest exporter of cotton as well as the seventh-largest world producer of gold. It is also a regionally significant producer of natural gas, coal, copper, oil, silver and uranium (World Bank, 2020). The concentration of economic production in the primary sector, however, hampers broad-based, value-added growth. Uzbekistan also receives the lowest foreign direct investment (FDI) in Central Asia (70% of FDI is targeted at neighbouring Khazakstan) (Metaxas and Kechagia, 2016).

The country's ambitious New Development Strategy was launched in 2017 (Tashkent Times, 2017) to support its transition to democracy, with the following key focus areas: state and judicial reform, economic liberalisation and growth, and social and cultural development and cohesion, including creating a foreign policy enabling regional cooperation. Economic liberalisation and growth includes *inter alia* initiatives focused on the creation of industrial zones and techno parks, export facilitation and transport infrastructure development. These initiatives become even more pertinent given Uzbekistan's double-landlocked status (all neighbours are also landlocked), making the country reliant on both infrastructure and relationships with neighbouring countries to reach international markets (Qoraboyev, 2018).

Uzbekistan is also a key role-player in the China-Central Asia-West Asia Economic Corridor, one of the six economic corridors in China's BRI – the improvement and expansion of cooperation, development and economic links between Asia, Africa and Europe – of which Central Asia is a key node. The BRI, in turn, can facilitate the expansion of commercial and trade routes for Uzbekistan, enabling regional connectivity, furthering trade, investment and infrastructure development. The BRIs multi-trillion dollar logistics infrastructure investment programme will bring about a redefinition of the international geopolitical and economic landscape. The engineering of local ownership in target countries is widely seen as necessary for the realisation of the BRI. In this context, local ownership refers to the expansion of regional and bilateral consultations in the BRI planning, and the integration of target country strategies, goals and concerns into the BRI (Qoraboyev, 2018).

It is therefore imperative for Uzbekistan to develop a clear understanding of its own national logistics needs and priorities to leverage opportunities for connectivity created by the opening of the country and initiatives in the Central Asian region. The Strategy for the Development of the Transport System of the Republic of Uzbekistan until 2035 was adopted by the government of Uzbekistan in 2019 (Dadabaev and Djalilova, 2020). It focuses on developing an integrated multimodal transport system, with national transport corridors improving regional interconnectedness and ensuring reliable and cost-effective hinterland access to transport infrastructure and services to reach domestic and export markets. Key success factors to realise this are increased competition in the transport market, development of public-private partnerships and an improved governance and regulatory environment to support integrated national logistics infrastructure investment and maintenance (OECD, 2019; World Bank, 2020).

However, within Uzbekistan the focus has been on physical planning of transport infrastructure assets without explicitly considering the demand for freight transport and intermodal competition (World Bank, 2020). Accurate, timely, and reliable information is the foundation of sound national and regional logistics sector policy-making and investment decisions (Asian Development Bank, 2007); the absence of which remains a critical barrier for the sector's sustainability and environmental performance, especially in emerging economies (Moon, 2013). Moon (2013) refers to a 'production-transport nexus' where, for many emerging economies, inadequate logistics services hamper production and income generation opportunities for economic players which, in turn, hamper their ability to pay for and develop logistics services.

One tool to step out of this negative cycle is to have the ability to target the sectors and logistics facilities which would not only enable short term growth opportunities, but would align with the economic development agendas of government and business over the long term. This is enabled through integrated data on the national transport and logistics industry with sufficient commodity and geographical disaggregation. Given the typical paucity of such data in emerging economies, this research describes the development of a freight-flow model for Uzbekistan – the Uzbekistan Freight-Flow Model (UFFM) – leveraging existing data sources. Both domestic flows within Uzbekistan, as well as freight-related movements beyond the borders of Uzbekistan, are included.

The UFFM was developed with support from the Government of Uzbekistan based on three drivers, i.e. the conviction that Special Economic Zones (SEZs) were required (Kuzieva, 2019); that the railway must improve (despite of its sizable network, the railway only shipped 68.4 million tonnes in 2018, albeit up from 61.5 million tonnes in 2012 (Sultanovich, 2019)); and that a data-driven transport strategy for Uzbekistan is required. However, from exploratory discussions, given the country's centrally planned economic history, it was clear that there would be challenges to readily obtain the detailed data required for the UFFM (further discussed in the methodology section). The primary aim was therefore to develop a freight-flow model with sufficiently detailed outputs to develop a cogent macrologistics narrative with evident application in the country's development strategies. The resulting secondary aim was to pique the interest of stakeholders to obtain wider access to data sources in order to refine the UFFM.

The structure of this article is as follows. Firstly, an overview of research approaches in data-scarce environments is provided to serve as context for the relevance of the applied research methodology. This is followed by a description of the UFFM methodology, including research limitations. The high-level outputs of the UFFM and related logistics costs model are then discussed, followed by an identification of the country's key macrologistics challenges, as well as potential domestic improvement opportunities. The concluding remarks summarise the outputs and suggest next steps. A comparison of the UFFM outputs to available data sources is provided in Annexure A, pointing to potential challenges with these data sources.

## 2 Research approaches in data-scarce environments

The United States Department of Transportation (2019) provides guidelines on data collection, compilation and refinement to support freight planning and forecasting (1) identify and assess available data sources and identify gaps; (2) collect, refine and clean existing data to create a base dataset of existing freight data; (3) collaborate with freight stakeholders to collect or estimate identified gaps; (4) process and combine existing and new data to create an integrated freight database; (5) create a process to maintain and update the freight database.

However, in emerging economies projects to improve data collection, accuracy and availability often fail because their goals are too ambitious, as the resources simply are not available to implement large-scale projects. This remains a key obstacle to the development of coherent national and regional transport policies and subsequent investments (Asian Development Bank, 2007).

To overcome the research limitations imposed by freight-flow data paucity, researchers often utilise the principle of data triangulation, i.e. the use of data from different sources to overcome the challenge of incomplete or conflicting datasets, to deepen understanding of the sector, and to cross-validate findings to increase the credibility of outputs (Mangan et al., 2004; Islam, 2005; Rahman, et al., 2017). The concept of triangulation refers to the trigonometric approach utilised in land surveying to determine unknown distances by measuring the angles in a triangle formed by three survey control points, i.e. two points on baseline with known distance and a distant third point in line-of-sight (Shafer, 1987). Through various iterations utilising the newly developed data a chain of triangles or triangulation network can be developed to describe the landscape under survey. Outputs of the triangulation network are strengthened by increasing the observations or inputs (Moose and Henriksen, 1976). The important principles are that known data points can be utilised to estimate unknown data points, that estimates can be improved by utilising more data inputs, and that this iterative process can eventually lead to a reliable description of the whole landscape under investigation if done diligently. A further approach to enhance triangulation is the Pareto principle in that significant commodities and regions were investigated in more detail.

In a model to estimate maritime carbon emissions from international trade, Schim van der Loeff et al. (2018) address the historical lack of data on this subject through linking and integrating a large number of data sources, previously used in isolation. The authors link per vessel cargo composition data, individual vessel journeys and a bottom-up methodology to estimate emissions, using vessel specifications and details on their movements and operations. Data is triangulated with data available from other sources, either in aggregate or for specific variables used in the model.

Even in the case of developed economies, Müller et al. (2012) refer to the ‘scarcity of representative data’ to build a large-scale freight-flow model for Germany, ‘therefore, it is necessary to expand and specify the benefit of given data by skilful handling and combination’ (although, naturally, much more data is available than in emerging economies). The goal was to develop a nation-wide, scalable, multimodal freight-flow model based on the translation of existing data into freight flow estimates with spatial and commodity-level detail to allow for an understanding of the heterogeneity of freight transport needs.

Islam (2005) combined research methods (a literature survey, a quantitative survey and a two-round qualitative Delphi study) to analyse the extent to which the transformation of a fragmented freight transport system into an integrated multimodal transport system depends on the present state of the country. Mangan et al. (2004) utilises a triangulated research approach to determine how decision-makers select seaport/ferry options for roll-on/roll-off freight between Ireland, the UK and Continental Europe, while Pourabdollahi et al. (2012) developed a nationwide freight micro-simulation model for the United States using several public data sources and results of a nationwide establishment survey.

The integration of a number of data sources is therefore a relatively common practice in freight-flow modelling at various level of disaggregation due to the typical lack of data to address pressing macrologistics issues. In addition to creative usage of available data, Chaberek and Mańkowski (2019) emphasise the need for “the right methods and tools” to develop a holistic map or model of the national logistics system for effective management of the sector. These methods and tools must view the logistics system in relation to the broader economy, not as an isolated activity. To facilitate this, the authors apply the national Input-Output tables to model Poland’s macro-logistics flows.

Schim van der Loeff et al. (2018) emphasise the value of spatially-explicit modelling to understand causality between demand for a commodity from a specific origin and its associated logistics need and impact, both direct and with regards to externalities. This increases the policy relevance of freight logistics modelling. Alises and Vassallo (2016) underscore that changes in economic production structures, such as growth in services, need to be reflected in freight-flow models as these changes have a significant impact on freight transport demand. They apply an Input-Output model to link shifts in the economic structure with road transport intensity in Spain and the UK, highlighting that similar GDP growth levels could lead to dissimilar road transport volumes depending on the evolution of economic activity in a specific country.

The literature therefore informs two principles for application in the freight-flow modelling approach for Uzbekistan. Firstly, the use of a combination of input data sources that is verified through an iterative process of triangulation and, secondly, the need for spatially and commodity explicit modelling inputs and outputs to increase the macrologistics relevance of the modelling outputs. Asian Development Bank (2007) however caution that “success is more likely if initial aspirations are modest, and data collection improved and widened progressively once initial systems are operating smoothly. This approach also provides the opportunity to prove the worth of improved data to users and to build a constituency that will support the funding necessary to expand the system”.

A hybrid or triangulated research approach is therefore adopted for the UFFM, with a specific emphasis on developing spatial and commodity characteristics of freight flows. This approach is detailed in the next section.

## 3 Methodology

### 3.1 Uzbekistan freight flow model

The methodology for developing a freight flow model and related logistics costs model for Uzbekistan is a gravity model based on the supply of and demand for commodities within the economy (World Bank, 2020).

Supply comprises local production and imports; while demand incorporates intermediate demand, final consumption, and exports. Due to the vast differences in the limited data available, the analysis aligned all the data to the major commodities in the customs data of UN Comtrade, as per Table 1. These commodity groups were selected based on a Pareto analysis of the customs trade data.

**Table 2: List of commodities used for Uzbekistan Freight-Flow Model (based on Uzbekistan customs trade data)**

| # | Commodity Name | # | Commodity Name |
|---|---|---|---|
| 1 | Agricultural products | 19 | Natural gas |
| 2 | Alcohol and tobacco products | 20 | Natural resources |
| 3 | Ceramic products (brick, tile, sink, dishes) | 21 | Oil and petroleum products |
| 4 | Chemical industry products | 22 | Paper, cardboard and products made of them |
| 5 | Cotton fibre | 23 | Animal feed |
| 6 | Cotton yarn | 24 | Pharmaceutical products |
| 7 | Electronic equipment and their parts | 25 | Plastics and articles thereof, film |
| 8 | Equipment and parts | 26 | Products made of stone, gypsum, cement, etc. |
| 9 | Finished household products | 27 | Pumps |
| 10 | Food | 28 | Rubber and products |
| 11 | Fruits and vegetables | 29 | Shoes and its details |
| 12 | Furniture and its parts | 30 | Textile products |
| 13 | Glass and glassware | 31 | Timber and products made of them |
| 14 | Hygiene products | 32 | Toys |
| 15 | Live animals, birds and their parts | 33 | Trees, plants |
| 16 | Metals and products made of them | 34 | Vehicles and their accessories |
| 17 | Mineral fertilisers | 35 | Weapons and ammunition, military equipment |
| 18 | Musical instruments | 36 | Wool, fur, skins, leather and products |

Total supply and demand per commodity were developed for each district. Total supply per district is depicted in Figure 1. (Freight maps are available for total demand, as well as supply and demand for each commodity).

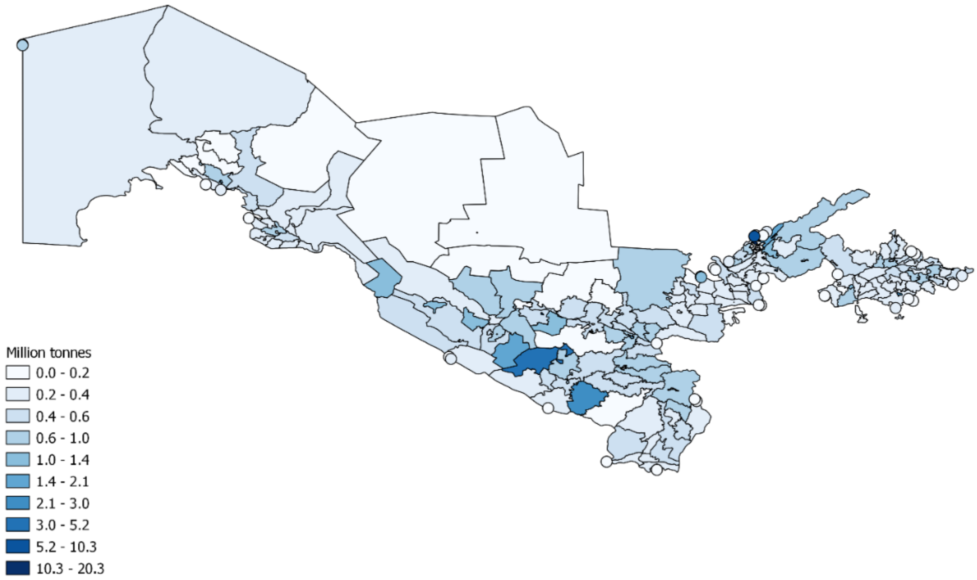


**Figure 5: Total supply per district in Uzbekistan**

Data was triangulated between the following main data sources:

1. Agriculture statistics (State Statistics Committee of the Republic of Uzbekistan)
2. 2017 Livestock statistics (State Statistics Committee of the Republic of Uzbekistan)
3. Industry statistics (State Statistics Committee of the Republic of Uzbekistan)
4. Labor and Demography statistics (State Statistics Committee of the Republic of Uzbekistan)
5. 2017 Road and Rail Data (Uzbekistan State Customs Committee)
6. 2017 trade data (UN Comtrade)
7. Uzbekistan Administrative areas shapefile (Humanitarian Exchange Data)
8. Spatial data (Open Street Map)

Data sources 1 – 4 are reported by the State Statistics committee on a district level. It provides the production (supply) of agriculture, livestock, mining and manufacturing, as well as population and employment statistics.

Data source 5, the road and rail data from customs, gives a breakdown of the tonnes imported and exported by Uzbekistan for a list of 37 commodities (of which electrical power is also one that is ignored). It also provides the volumes of tonnes of import and export freight that crossed at each road and rail border post. A distinction is made between import, export and transit freight entering or leaving the country.

For the sake of simplicity, data sources 1 – 4 were aligned to the customs data providing a production estimate for the 36 commodities per district (refer Table 1), even though these sources were highly detailed, such as the manufacturing industry data consisting of 2178 unique commodities.

Due to the significance of border operations and cross-border data, the double-landlocked geography of Uzbekistan, and based on the Pareto principle that was followed, a detailed approach for cross-border data generation was followed, using the data triangulation process described in Section 2. The breakdown per border post for road and rail does not specify which of the 36 commodity categories were imported or exported. 2017 UN Comtrade data was therefore used from each country reporting to have traded with Uzbekistan in 2017, because UN Comtrade does not have any data reported by Uzbekistan itself. The reporting countries were grouped according to which border country (Afghanistan, Turkmenistan, Kazakhstan, Kyrgyzstan, Tajikistan) their freight would most likely be entering Uzbekistan.

Table 2 shows the distribution through which border country freight is entering Uzbekistan. The country allocations were done on an all-or-nothing approach, therefore it was assumed that imports from and exports to each respective country will be passing through the same border post.

**Table 3: Border country distribution – Imports comparison between data sources**

| Border country | Import distribution - Customs | Import distribution – UN Comtrade |
|---|---|---|
| Kazakhstan | 89% | 88% |
| Kyrgyzstan | 5% | 6% |
| Turkmenistan | 4% | 4% |
| Tajikistan | 2% | 0% |
| Afghanistan | 0% | 2% |

Table 3 shows the border country distribution for exports. It should be noted that the large differences are explained due to the absence of 2017 UN Comtrade data for Afghanistan, Turkmenistan and Tajikistan, skewing the distribution toward Kazakhstan.

**Table 4: Border country distribution - Exports comparison between data sources**

| Border country | Export distribution - Customs | Export distribution – UN Comtrade |
|---|---|---|
| Kazakhstan | 51% | 85% |
| Afghanistan | 20% | 7% |
| Turkmenistan | 19% | 3% |
| Kyrgyzstan | 5% | 4% |
| Tajikistan | 5% | 0% |

After classifying the UN Comtrade HS-4 commodity codes[7] to the list of 36 commodities from data source no. 5 (Customs data) a commodity distribution was calculated for each border post. This distribution was assigned to each border post of the neighbouring country. Therefore for border post $i$ with a freight volume of $t_i$, the freight for each commodity $j$ is calculated from each trading partner $l$'s UN Comtrade freight volumes, $t_{ljk}$ that imports or exports freight via bordering country $k$, $t_{ijk}$ is calculated as follows:

$$t_{ijk} = t_i \frac{t_{ljk}}{\sum_l \sum_j t_{ljk}}$$

[7] The Harmonized Commodity Description and Coding Systems (HS) is an international nomenclature for the classification of products. It allows participating countries to classify traded goods on a common basis for customs purposes. HS-2 is the main chapter of goods, while HS-4 identifies groups in the chapter, and HS-6 provides a further disaggregation (United Nations, 2017). HS-4 is sufficiently detailed for disaggregated freight-flow analysis purposes.

$t_{ijk}$ is then normalised to the commodity import and export totals for Uzbekistan to give the final volume $T_{ijk}$ per border post for road and rail border posts, given the total import (or export) of commodity $j$ reported by customs $I_j$:

$$T_{ijk} = I_j \frac{\frac{t_{ljk}}{\sum_k t_{ljk}}}{\sum_j I_j}$$

This provides supply (imports) and demand (exports) totals for the border posts. Transit freight per border post was estimated on the same principles as for the imports and exports, using the transit freight per border post from the Uzbekistan customs data, but excluding the final normalisation step. Trade between the countries in Table 4 (and their reverse flows) were used to split the transit tonnes per border posts into the 36 customs commodities.

**Table 5: Countries identified to produce the commodity splits for transit freight passing through Uzbekistan**

| Origin country | Border entry country | Border exit country | Destination country |
|---|---|---|---|
| Russia | Kazakhstan | Turkmenistan | Turkmenistan |
| Kazakhstan | Kazakhstan | Turkmenistan | Turkmenistan |
| China | Kazakhstan | Turkmenistan | Turkmenistan |
| Mongolia | Kazakhstan | Turkmenistan | Turkmenistan |
| Russia | Kazakhstan | Afghanistan | Afghanistan |
| Kazakhstan | Kazakhstan | Afghanistan | Afghanistan |
| China | Kazakhstan | Afghanistan | Afghanistan |
| Mongolia | Kazakhstan | Afghanistan | Afghanistan |
| Kazakhstan | Kazakhstan | Turkmenistan | Iran |
| Russia | Kazakhstan | Tajikistan | Tajikistan |
| Kazakhstan | Kazakhstan | Tajikistan | Tajikistan |
| China | Kazakhstan | Tajikistan | Tajikistan |
| Mongolia | Kazakhstan | Tajikistan | Tajikistan |
| Russia | Kazakhstan | Afghanistan | Pakistan |
| Kazakhstan | Kazakhstan | Afghanistan | Pakistan |
| Poland | Kazakhstan | Afghanistan | Afghanistan |
| Slovakia | Kazakhstan | Afghanistan | Afghanistan |
| Belarus | Kazakhstan | Afghanistan | Afghanistan |
| Latvia | Kazakhstan | Afghanistan | Afghanistan |
| Estonia | Kazakhstan | Afghanistan | Afghanistan |
| Finland | Kazakhstan | Afghanistan | Afghanistan |

| Origin country | Border entry country | Border exit country | Destination country |
|---|---|---|---|
| Poland | Kazakhstan | Tajikistan | Tajikistan |
| Slovakia | Kazakhstan | Tajikistan | Tajikistan |
| Belarus | Kazakhstan | Tajikistan | Tajikistan |
| Latvia | Kazakhstan | Tajikistan | Tajikistan |
| Estonia | Kazakhstan | Tajikistan | Tajikistan |
| Finland | Kazakhstan | Tajikistan | Tajikistan |
| Belarus | Turkmenistan | Kyrgyzstan | Kyrgyzstan |
| Georgia | Turkmenistan | Kyrgyzstan | Kyrgyzstan |
| India | Turkmenistan | Kyrgyzstan | Kyrgyzstan |

The transit splits per bordering country derived from the identified countries in Table 4 produced the splits that can be seen in Table 5. The entry freight is skewed towards Kazakhstan because of the all-or-nothing assignment. This could potentially be refined further to give a vector of distributions between each transit country pair and the bordering countries. The exit freight is skewed towards Turkmenistan away from Tajikistan for the same reason, as well as the mirror of flows for the sake of simplicity.

**Table 6: Transit border entry country and exit country freight splits derived from UN Comtrade trade data**

| Border post | Entry transit distribution | | | Exit transit distribution | |
|---|---|---|---|---|---|
| | Customs | UN Comtrade | | Customs | UN Comtrade |
| Kazakhstan | 82% | 91% | | 8% | 8% |
| Turkmenistan | 9% | 4% | | 8% | 29% |
| Tajikistan | 8% | 3% | | 49% | 28% |
| Kyrgyzstan | 1% | 1% | | 2% | 0% |
| Afghanistan | 0% | 1% | | 33% | 34% |

The supply is directly provided by data sources 1 – 4 per district. The demand per commodity is determined through disaggregating the supply totals based on the domestic demand. The domestic demand is determined as the supply + imports – exports. The local supply of commodities with a negative domestic demand was inflated to increase the local supply.

Most commodities were disaggregated by population per district with the exception of the commodities which can be seen in Table 6.

**Table 7: Commodities for which demand was not disaggregated by population**

| Commodity | Proxy for disaggregation |
|---|---|
| Live animals, birds and their parts | Demand of live animals weighted between supply of food (50%) and wool leather and skins (50%) |
| Mineral fertilisers | Demand at the supply point of agricultural products; supply inflated to account for the exports and local demand |
| Agricultural products | Demand disaggregated by Industrial employment |
| Chemical industry products | Demand disaggregated by Industrial employment |
| Cotton fibre | Demand disaggregated by Industrial employment |
| Cotton yarn | Demand disaggregated by Industrial employment |
| Electronic equipment and their parts | Demand disaggregated by Industrial employment |

Open Street Map spatial data was processed to produce a road network and to obtain a rail network. The rail network was used to determine which districts are accessible by rail on the principle that rail imports and modal shift can only be facilitated in the districts with rail connectivity.

The supply and demand tables were processed into origin-destination (OD) flows via a gravity model using the network distance derived from the open street map spatial data as impedance input.

Assumed rail volumes were derived from OD pairs with both origin and destination districts with rail connectivity, and rail suitability per commodity. High percentages per commodity were applied to get within the range of rail volumes, but tonne-kilometers did not match as well. Receiving rail origin-destination commodity data would have negated these assumptions (refer section 3.2).

Transport costs were derived from published rail costs and tariffs of Uzbekistan railway, while road rates were obtained from published rates of transporters. For logistics costs, a similar relative ratio to other comparative countries was used, using transport costs as the proxy for other components.

The next step was to populate and run the UFFM and use the outputs to describe the logistics landscape of Uzbekistan. However, data limitations first need to be highlighted in the next section.

### 3.2 Data limitations

As mentioned in the introduction, there were challenges to readily obtain the detailed data required for the UFFM. Firstly, not only is there a lack of data, but the legacies of the authoritarian structure of government remain a hindrance despite reforms (Omelicheva, 2016; Bowyer, 2018); data is often protected and foreign involvement is questioned (Spechler, 2007). Secondly, Uzbekistan, being one of two only double-landlocked countries in the world, relies heavily on its central position in Central Asia, but at the same time many production factors are managed from outside the country. Landlocked countries normally face challenges to access world markets and lag neighbours in development and trade (Faye et al., 2004). For a double-landlocked country, where neighbours have similar problems, this situation is exacerbated. These factors further hinder the ability of researchers to gain access to relevant data.

The following data limitations need to be addressed in future iterations of the model:

- Rail data, which is commonly available in most countries could not be sourced adequately. The data does exist, but could not be accessed because of legacy data systems.
- The breakdown per border post for road and rail does not specify which of the 36 commodity categories were imported or exported.
- The absence of 2017 UN Comtrade export data for Afghanistan, Turkmenistan and Tajikistan at time of creation.
- The transit entry freight is skewed towards Kazakhstan because of the all-or-nothing assignment; this could potentially be refined to give a vector of distributions between each transit country pair and the bordering countries. The exit freight is skewed towards Turkmenistan away from Tajikistan for the same reason.

The next section illustrates the type of macrologistics analysis possible with the UFFM outputs based on the data that has been obtained, providing impetus for access to additional data to refine the outputs and confirm macrologistics interventions. At the outset, however, a brief overview of Uzbekistan's Logistics Performance Index ranking is provided for some context.

## 4 Key descriptors of the Uzbekistan macrologistics landscape

### 4.1 Logistics Performance Index

The Logistics Performance Index (LPI) of a country is often quoted in transport industry reports and strategy documents as it is an acknowledged global dataset with improved methodology over time (Puertas and Garcia, 2014), and often in emerging economies it is one of the few comparative statistics available. It is however a stand-alone assessment, often without contextual links and importance weighting of its components (Rezaei, et al., 2018). Limitations of the measure include, specifically, skewed measurements if a country is a 'victim' of outside control of its logistics system, exacerbated by being landlocked (Beysenbaev and Dus, 2020). The LPI alone cannot inform a macrologistics strategy, but if used as a springboard for research to follow can play a useful role.

In 2018, Uzbekistan's LPI position improved from number 118 to 99. Uzbekistan's overall score of 2.58 is on par with the lower-middle-income country's performance, with the country's score increasing on all but one LPI indicator between 2016 and 2018. Timeliness and consignment tracking improved markedly which can be traced back to improved regulation. The drop in the score of efficient customs and border management clearance ('customs' in Figure 1) is significant, given the country's dependence on freight outside of its borders (refer Section 4.2). In 2018, the government took steps to reform these areas, including customs, and to open several border posts. The changes and impacts of these reforms might be captured in the 2020 LPI results.

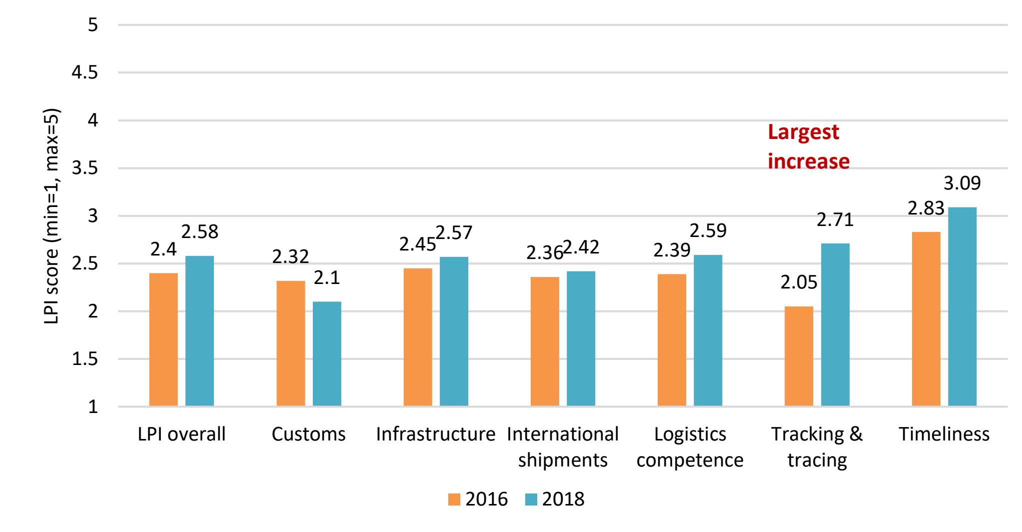


**Figure 6: Uzbekistan LPI components, 2016 vs. 2018 (Arvis et al., 2018)**

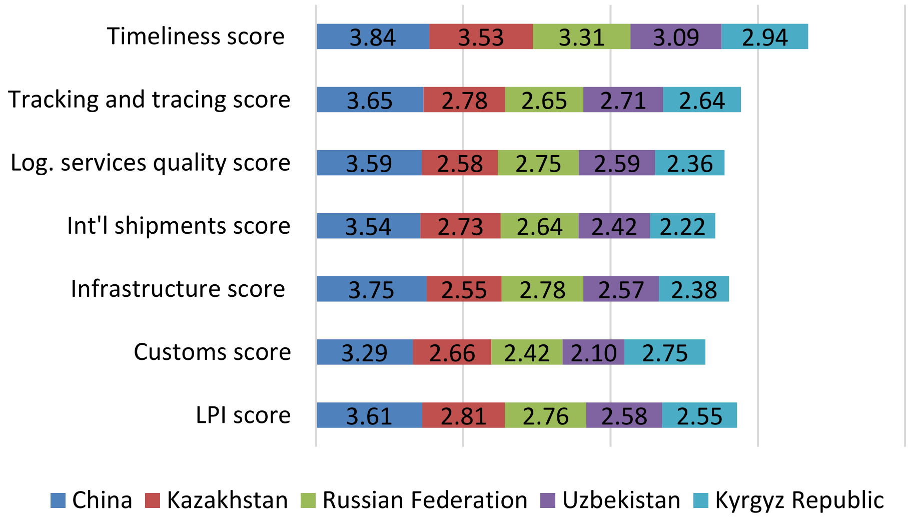


**Figure 7: Uzbekistan and comparators by LPI Component, 2018 (Arvis et al., 2018)**

This problem is reflected in the reality of Uzbekistan's freight flows which put a sharp focus on border and trade issues in a double-landlocked country, as discussed below.

### 4.2 Total freight flows

Based on the UFFM, freight demand for Uzbekistan within the borders of the country is 194.6 million tonnes and 77.6 billion tonne-kilometres (refer Figure 4). This includes all domestic freight flows and flows towards border posts for exports, as well as from border posts for imports. Transverse freight is excluded.

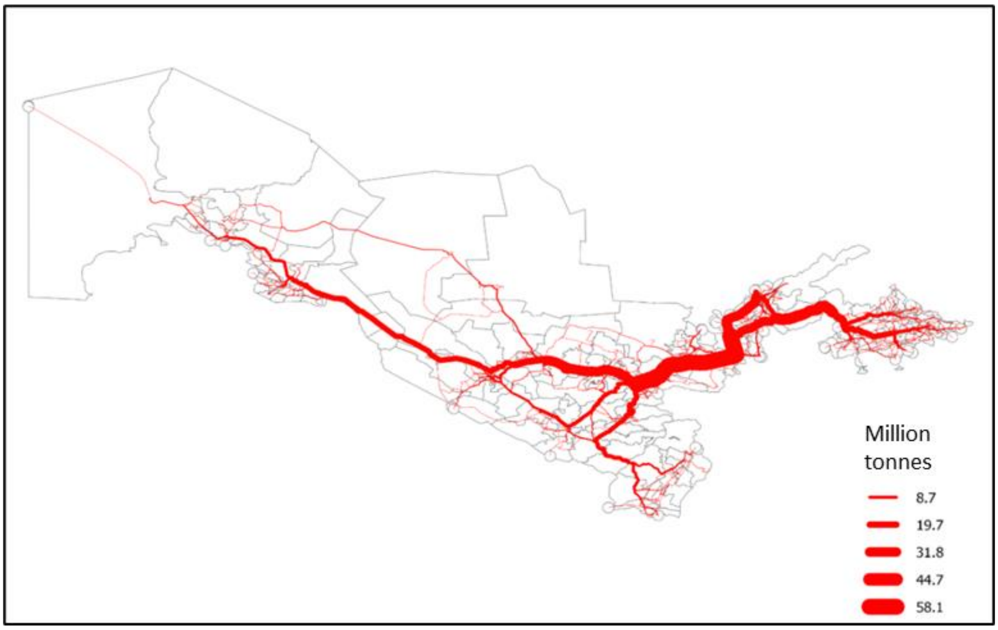


**Figure 8: Freight flows within Uzbekistan (data from: UFFM, 2017 data)**

If the freight flows to and from final destinations in foreign countries are added, freight demand increases with 60 billion tonne-kilometres to 138 billion tonne-kilometres (due to the added distance) (refer Figure 5). Simply put, to achieve Uzbekistan's final economic output 138 billion tonne-kilometres are required, 43% of which occurs outside of the country. This is exacerbated by the fact that cross border land operations don't have the very high efficiency possibilities as maritime trade, where a handful of global maritime merchant companies have developed inordinate coordination skills over the last few decades. Added to this problem is Uzbekistan's logistics service provider industry which is in its infancy and more or less all cross border operations is by non-Uzbekistan companies. This effect is confirmed by Grafe et al. (2008) who found that although regional market integration in Central Asia is quite high, borders do have a significant effect on price dispersion and that this effect is at its worst for Uzbekistan. Uzbekistan therefore has the highest border 'friction' in Central Asia, but at the same time is more dependent on cross border land trade than all countries in Central Asia.

A second problem in Uzbekistan is the natural shape of the country which essentially splits the country in two parts: an Eastern portion east of Samarkand and a Western portion west of Samarkand. Freight-flow distribution is heavily skewed towards the East. The east has 65% of freight supply and 57% of freight demand, but only 13.5% of the land area (data from UFFM) (Figure 6). At the same time the Gross Regional Product of regions to the West range from 23 to 36 thousand Soums per capita whereas the figure for the East range from 27 to 93 thousand Soums per capita in 1995 comparable prices (Qayumovna, 2021).

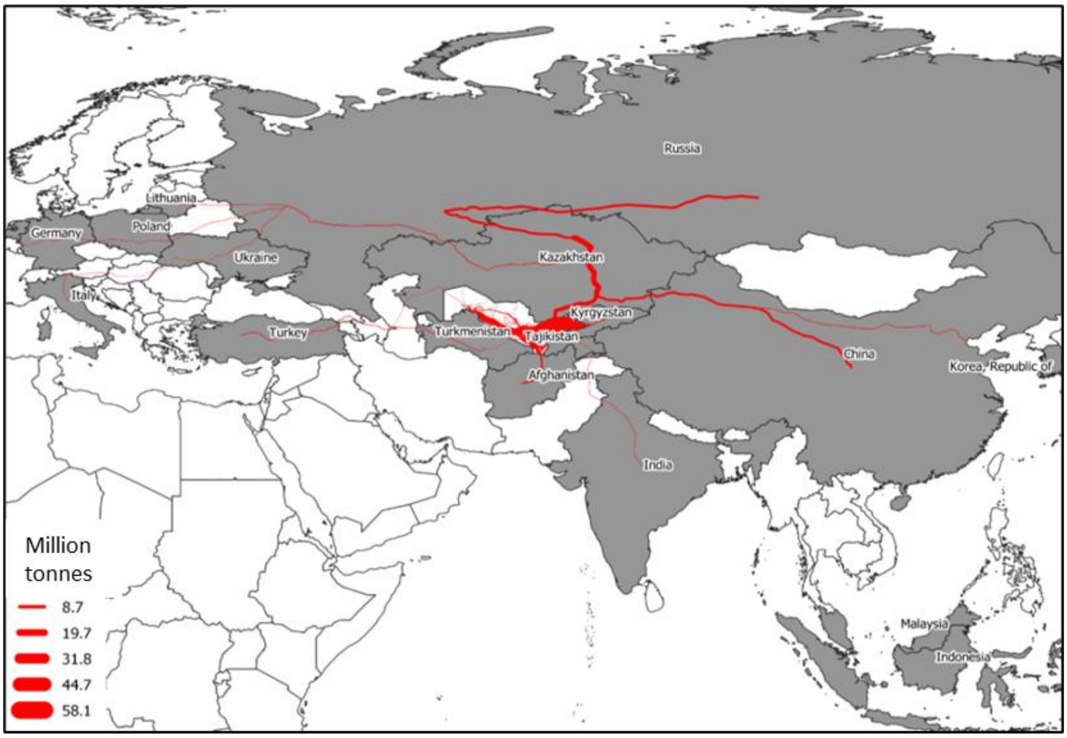


**Figure 9: Uzbekistan freight outside of the border (data from UFFM, 2017 data)**

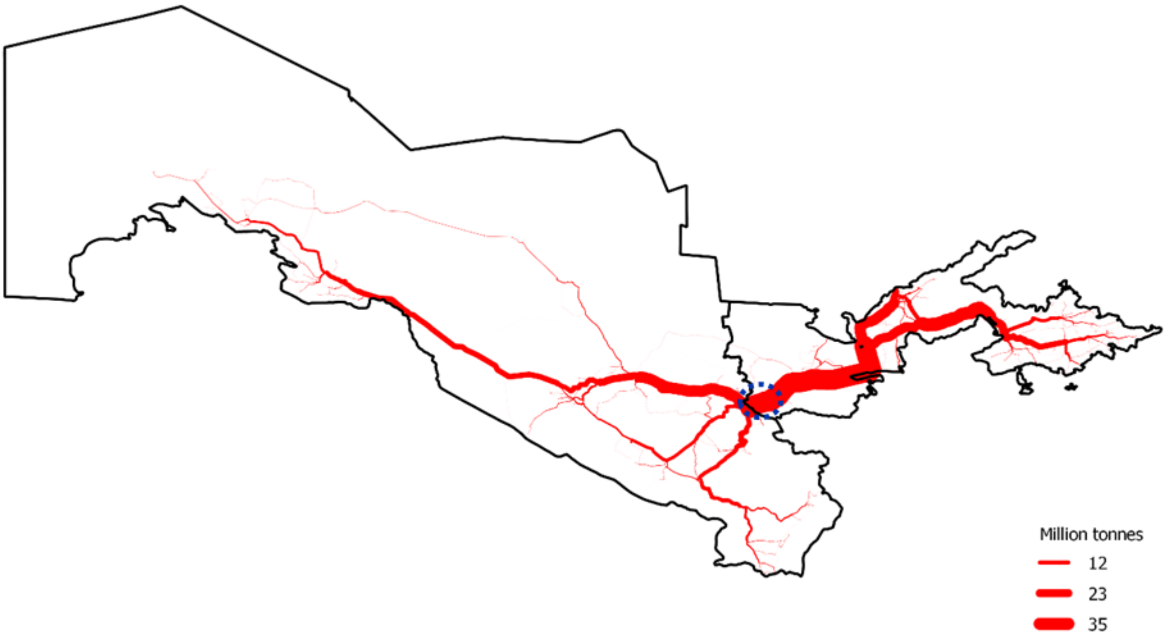


**Figure 10: Split of Eastern and Western freight flows, with Samarkand indicated by the dotted circle**

A logistics action plan should consider development objectives in the Western part of the country and strategies to streamline border crossings and exposure to freight risks beyond the borders due to the inordinate long distances of cross-border flows. This is therefore a spatial development problem and the absence of a powerful logistics hub to control logistics not only in the country, but in the region.

### 4.3 Uzbekistan's freight flow challenges in global context

Tonne-kilometre demand is high for Uzbekistan relative to the country's GDP. Uzbekistan's GDP is equal to 0.06% of the world GDP, but with a slightly relative larger land mass and much higher relative freight demand (refer Figure 7).

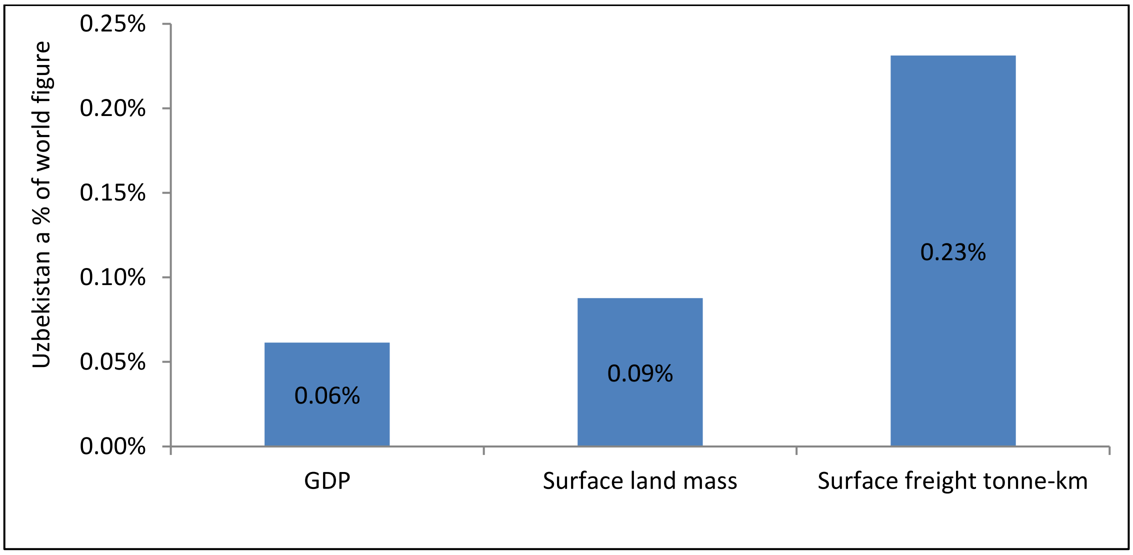


**Figure 11: Uzbekistan relative freight demand (2017 data) (source: Authors own calculations based on: World Bank, 2017)**

This can be further analysed by looking at the GDP productivity of the freight transported. The world's $74 (World Bank, 2017) trillion GDP requires around 32 trillion surface[8] tonne-kilometres (International Transport Forum, 2017) of inputs. This means that on average $2.30 of GDP is produced for every surface tonne-kilometre used in the world. Uzbekistan is part of a group of countries where tonne-kilometre 'productivity' is extremely low, i.e. $0.67 per tonne-kilometre (refer Figure 8). This renders transport a strategic national resource requiring national strategic attention to both reduce tonne-kilometre demand for transport and increase supply efficiency.

[8] Surface freight refers to road and rail transport

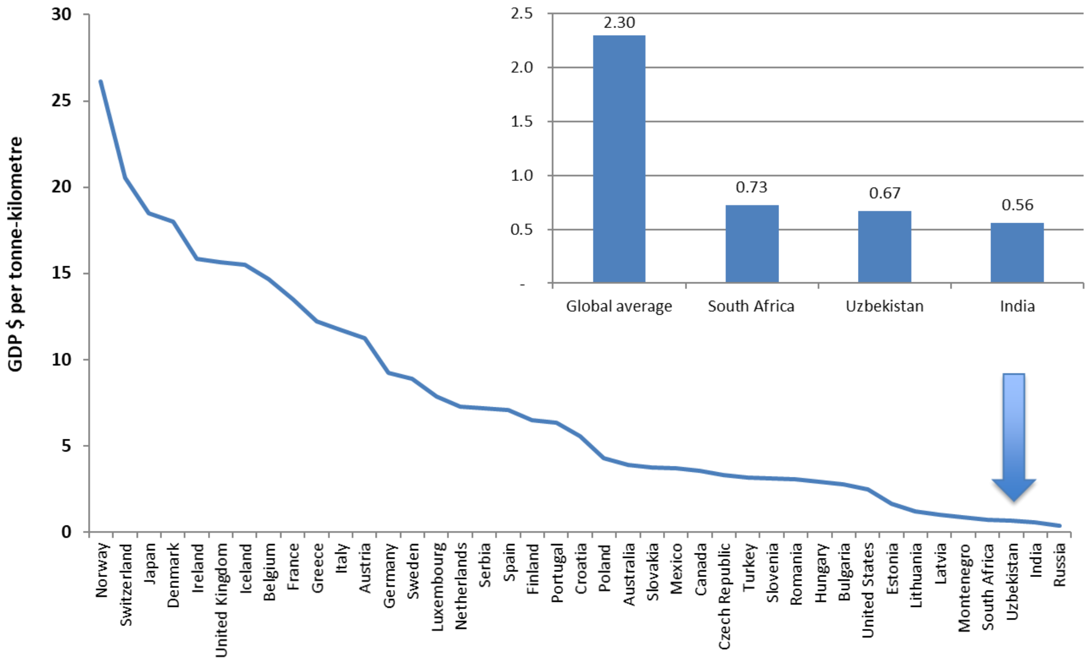


**Figure 12: Country-level comparison of $ GDP per tonne-kilometre (2015 and 2017 data) (based on: Bambulyak and Frantzen (2007), OECD (2010), US Department of Transport 2007, 2015 and 2017 data from World Bank, 2017)**

In terms of relative supply of transport infrastructure, Uzbekistan has an average road network, but a very large and extensive rail network (refer Figure 9). The rail network can serve as a platform to address much of the above-mentioned efficiency issues. It is important to evaluate freight flows more in-depth to inform the role the railways can play to solve domestic, but especially regional, freight-flow challenges (refer section on the improved use of the railway).

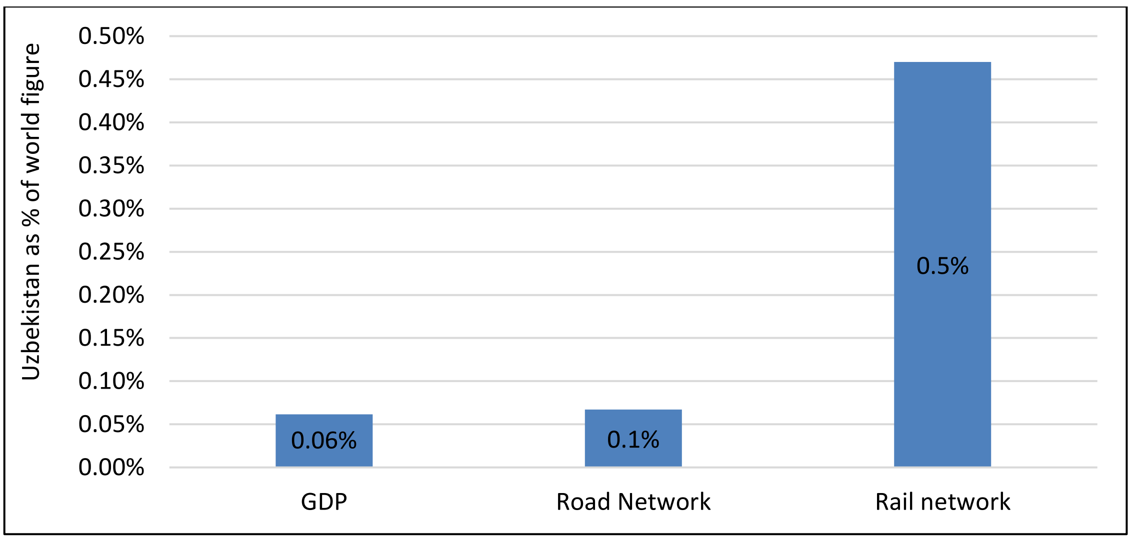


**Figure 13: Relative size of Uzbekistan's road and rail network in relation to global totals (2017 data) (based on: World Bank 2017, Asian Development Bank 2017, United Union of Railways)**

**5 Logistics costs**

Logistics costs comprise of transport costs, warehousing, inventory carrying costs, and management and administration costs.

Total transport costs for Uzbekistan is estimated at US$ 2.8 billion for 2017 (refer Figure 10), of which the majority is road transport costs.

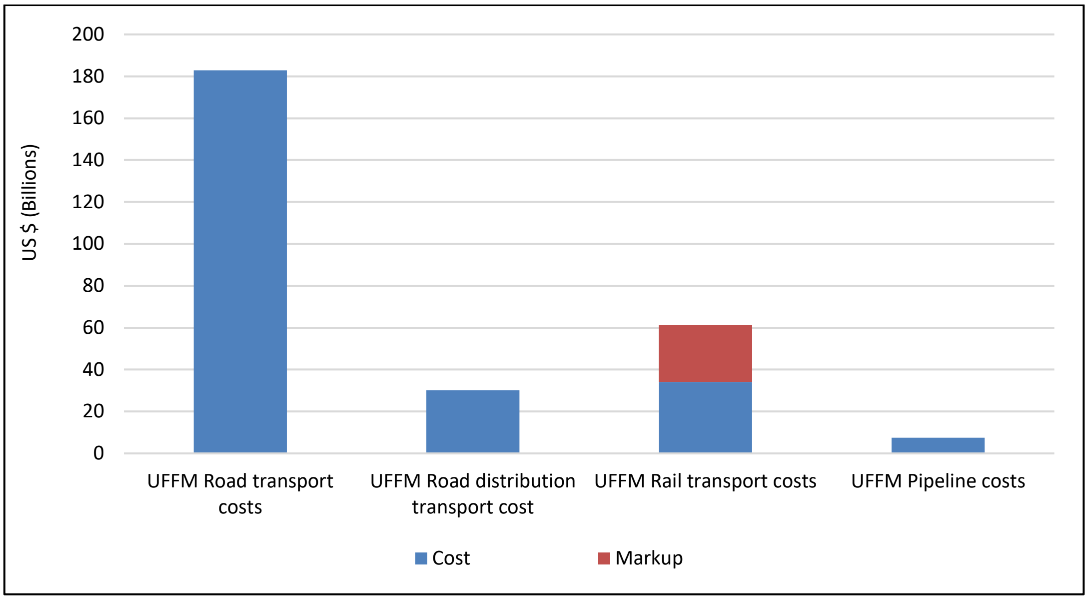


**Figure 14: National transport costs per mode for Uzbekistan (data from UFFM, 2017 data)**

Warehousing, inventory carrying costs, and management and administration costs add a further US$5.2bn, for a logistics costs estimate of US$ 8 billion for 2017 (refer Figure 11). This amounts to 16.5% of GDP, and 32.6% of transportable GDP (i.e. the GDP for mining, agriculture and manufacturing).

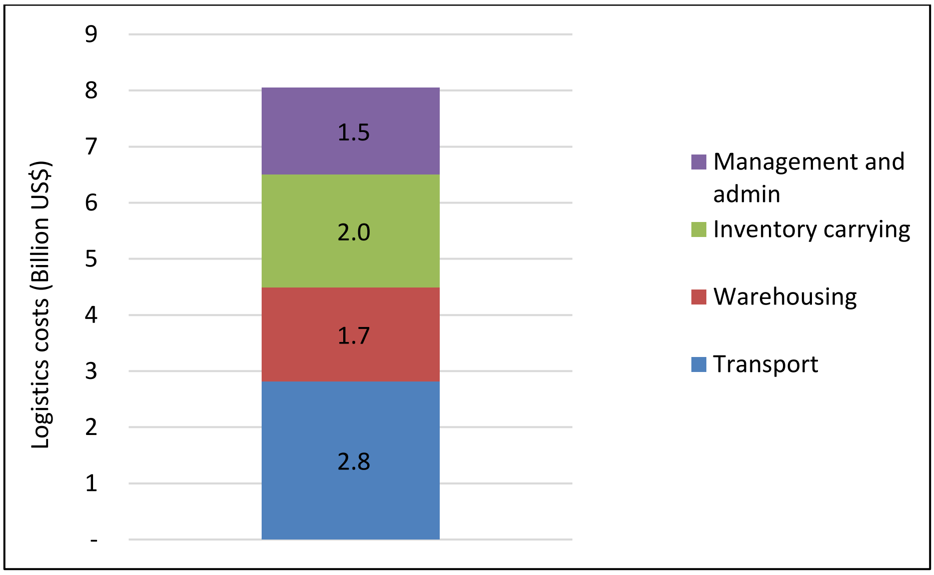


**Figure 15: National logistics costs for Uzbekistan (data from UFFM, 2017 data)**

Uzbekistan's logistics costs as percentage of GDP does not benchmark well with other nations (refer Figure 12). The ratio is always lower in the developed world (the USA is shown here for comparative purposes) and typically lower in emerging economies (the BRICS countries[9] are shown here for comparison). For countries with a comparable low services percentage of GDP, such as India and China, Uzbekistan also compares poorly.

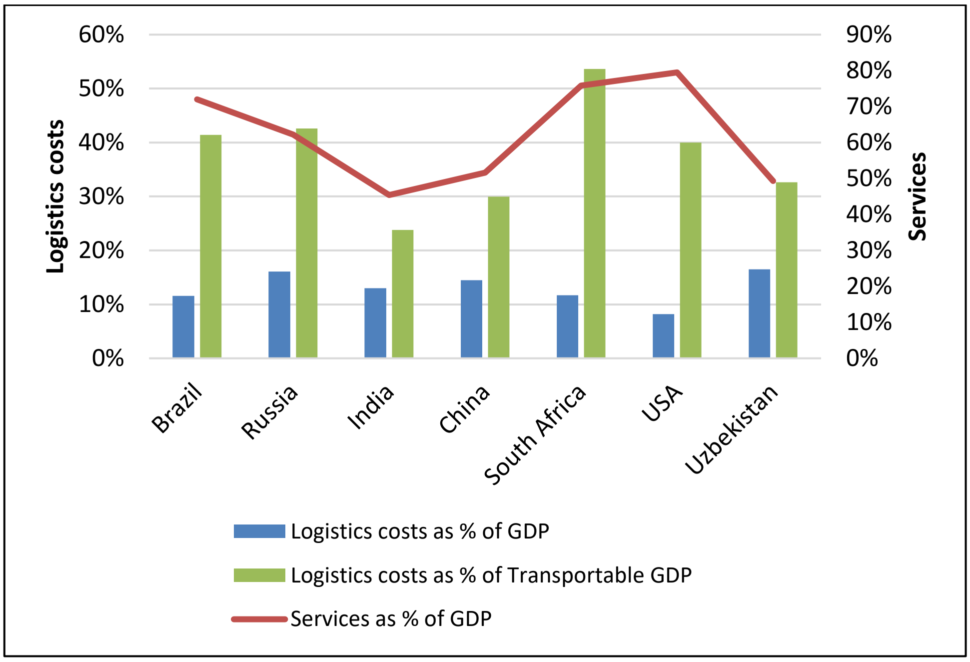


**Figure 16: Logistics costs as percentage of GDP for 2017 – country-level comparisons (Armstrong Associates Inc, Central Intelligence Agency)**

The take-outs from this analysis supports the narrative from the freight-flow analysis, namely that of the relative importance of logistics in the country's development strategy. Transport policy, infrastructure development and the role of transport and logistics in development planning should be prioritised as a strategic input into economic growth and development success. This means problems with development in the West, limited control over cross-border operations with significant cross-border transport demand, inordinately large transport demand relative to GDP, a fledging LSP industry and high logistics costs must be addressed.

## 6 Concept analysis – Domestic opportunities for improving

As mentioned, the model accuracy can be improved with access to outstanding data sources (refer Section 3.2). However, the author has enough confidence in the aggregate outputs to demonstrate its application in data-driven planning. Two key options were investigated, i.e. improved use of the railway, and the clustering of freight through the development of SEZs and, ultimately, freight villages. (1) The improved use of the railways can reduce transport costs, improve Uzbekistan's positioning in Central Asia and make it easier for the West to access markets; and (2) logistics centres (hubs or SEZs) can also through consolidation improve the locus of control of Uzbekistan to leverage the BRI. High-level outputs of these options are discussed below.

### 6.1 Improved use of the railway

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[9] An association of five major emerging national economies: Brazil, Russia, India, China and South Africa

As mentioned, Uzbekistan is relatively 'oversupplied' by rail if comparing the geographical and economic output size of the country with the rest of the world (refer Figure 9). Three avenues for improved use of the railway are considered namely modal shift, savings due to increased rail density, and savings due to improved rail efficiencies.

Using the UFFM it is estimated that around 21.9 million tonnes of freight or 17.9 billion tonne-kilometres can shift to rail, resulting in a transport cost saving of $430 million (due to lower rail costs). This shift will densify Uzbekistan's rail network which would result in a further decrease in costs of Uzbekistan rail freight by 17% as identified by the Harris-curve[10] for the country's railways (i.e. impacting all rail freight) (refer Figure 13). This should result in a further saving of $170 million.

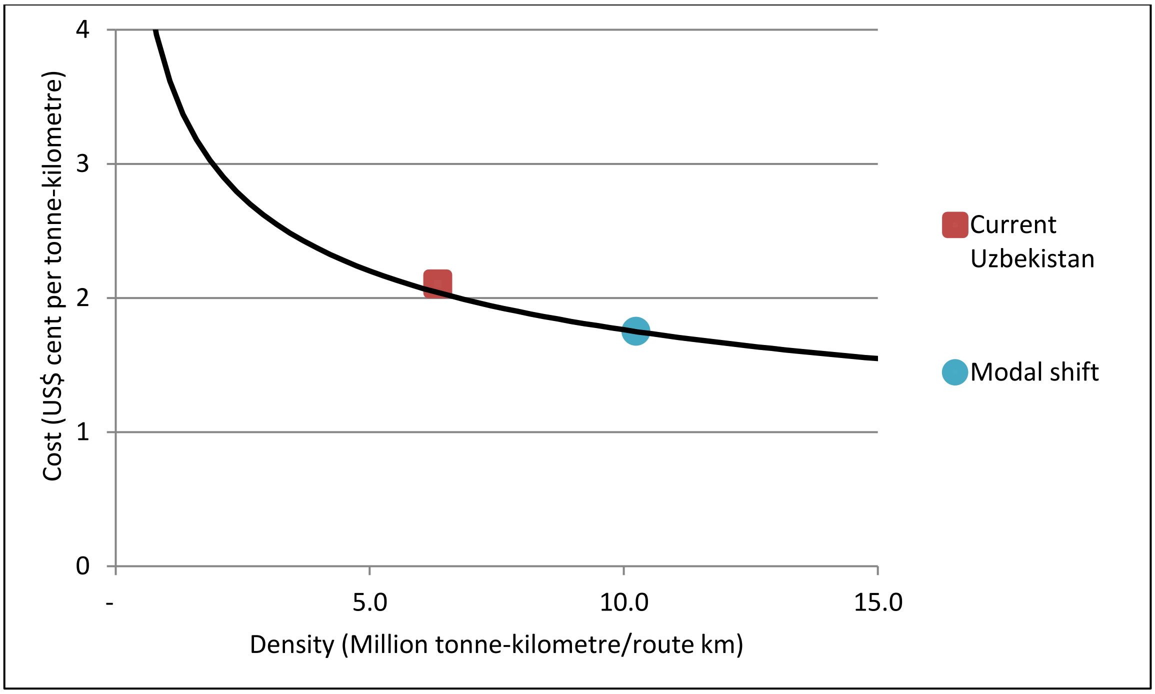


**Figure 17: Estimated transport cost reductions due to improved rail density (2017 data)**

Although not enough data is available for an accurate measurement, observations around margins and efficiency indicate that a further $180 million could be saved by making the railway more efficient, cost effective and with more sustainable and fair margins.

These combined savings can reduce logistics costs as percentage of GDP from 16.5% to 15.0%, and from 32.6% to 29.6% of transportable GDP. This should enable growth in other industries, increasing GDP (while partially increasing logistics costs due to new industries, following the initial saving – this requires further analysis). A shift of 1.5 percentage points of logistics costs as a percentage of GDP is significant for any country; this highlights an important opportunity for improvement and provides impetus for the refinement of the UFFM.

[10] The positive relationship between cost reduction and improvement in density was first demonstrated by Harris (1977). The potential cost savings experienced on rail due to modal shift can be attributed to a more favourable relationship between fixed and variable costs where more freight is available to absorb rail's high fixed costs

### 6.2 Clustering freight

Clustering freight in SEZs and, ultimately, freight villages, will have an important effect on Uzbekistan's logistics costs. Freight villages shorten distances in the supply chain, enable more accurate delivery windows, consolidate long-distance freight which facilitates modal shift and decreases the unit cost of both road and rail transport. Investment in a refined freight-flow model will enable improved freight village positioning and design.

It seems as if only 5% of current freight flows will be affected by the current design (of logistics centres or logistics hubs), but an improved design where between 10% and 20% of freight could be captured, is potentially achievable and would improve the success of freight villages. Such a design could reduce transport costs with at least another \$100 to \$200 million dollars (depending on the design of the freight villages).

## 7 Dependence on trade routes and logistics outside of the country

Most importantly, however, is Uzbekistan's exposure to the regional freight network design. If tonne-kilometres of Uzbekistan freight outside of the country is added to domestic freight the volume grows with 60 billion tonne-kilometres from 78 to 138 billion tonne-kilometres (refer Figure 14 for the modal split of this freight, and Figure 4 and Figure 5 for the mapped flows).

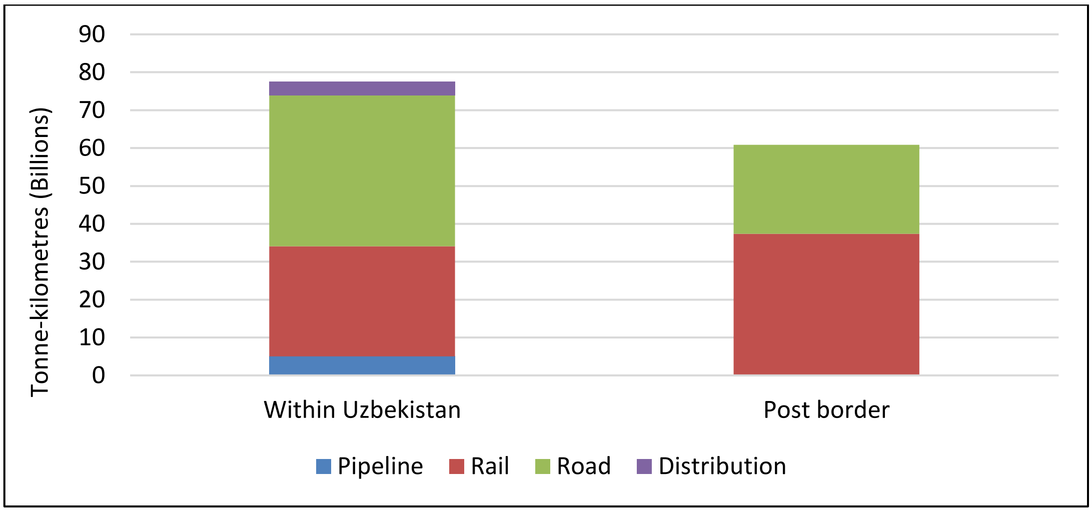


**Figure 18: Tonne-kilometres within and outside of Uzbekistan (data from UFFM, 2017 data)**

As a comparison, South Africa's 350 billion tonne-kilometres constitute only 20 billion tonne-kilometres added by overland or surface cross border freight (Figure 15). Countries such as South Africa require much more maritime freight for trade, but this freight is already, for the most part, efficiently consolidated, globally scheduled and part of an efficient global shipping line system. These conditions do not exist for a double-landlocked country and need to be created by a regional transport system that is run efficiently, similar to a global port and shipping line network.

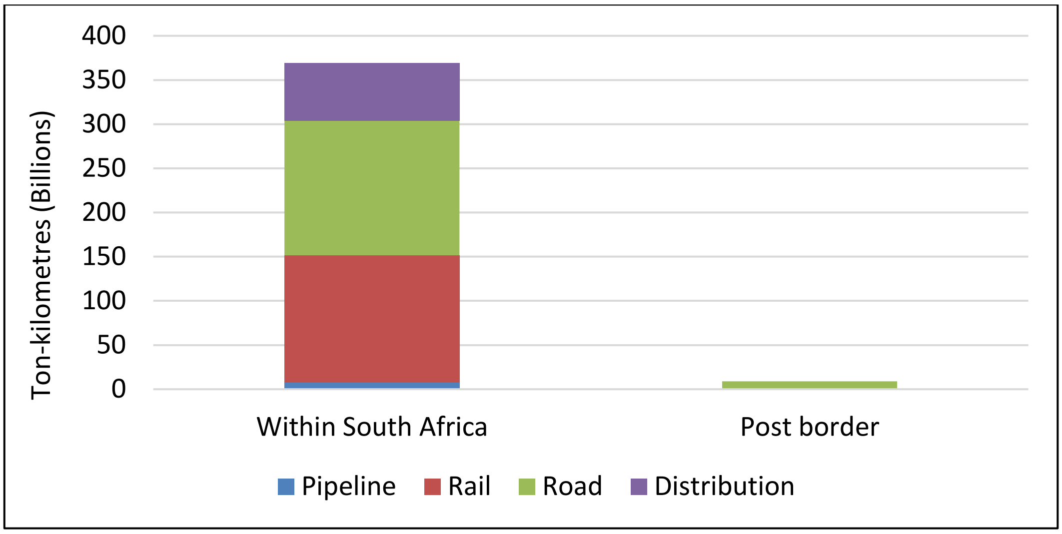


**Figure 19: Tonne-kilometres within and outside of South Africa[11] (data from South African freight-flow model)**

In terms of transport costs, this characteristic of the Uzbekistan freight system means that more money (52% of transport costs) is spent on freight transport costs outside of the country than within the country (refer Figure 16).

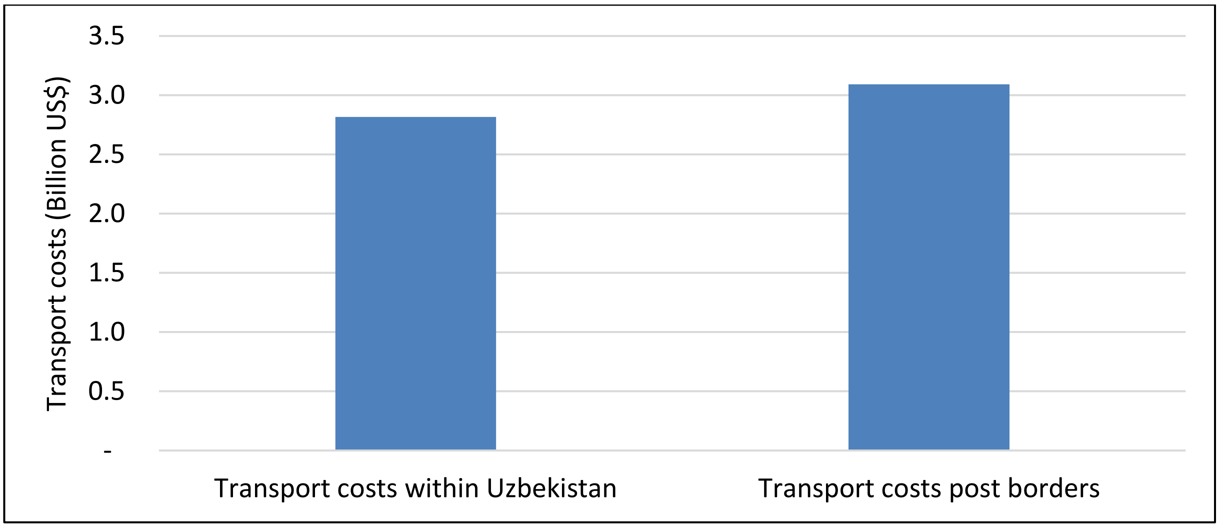


**Figure 20: Transport costs within and outside of Uzbekistan (data from UFFM, 2017)**

To compare this with South Africa with maritime costs included, South Africa's transport costs domestically is about $17 billion and internationally (both cross-border and maritime) about $7 billion, i.e. about 30% outside of the country compared to Uzbekistan's more than 50%.

This calls for increased focus on a regional efficiency drive, which will depend on:

- Local freight consolidation centres;
- Regional network planning; and
- Regional cooperation.

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[11] Excludes maritime freight, only includes cross-border surface freight.

## 8 Recommendations and action plan

Olofin et al. (2011) emphasise that an accurate, timely and systematic national statistical system is a prerequisite for national development (i.e. the fulfilment of a country's objectives), where this 'system' incorporates the people, procedures, data and equipment to bring it to fruition. As one of the backbones of a globalised economy, the expansion of national statistical systems to include freight logistics intelligence, is long overdue. The research highlighted key principles to support both the development and application of such national statistical systems are: a culture of research-driven policy decisions; establishment of an active data users' forum; development of robust models; capacity building; and enactment of an appropriate legal frameworks.

The following recommendations and action plan for Uzbekistan support these principles and are informed by the outputs of the UFFM:

1. *Manage transport and logistics as a strategic commodity.* This means that the Transport Ministry should, on the one hand, be capacitated adequately and given enough powers to effectively develop strategic solutions while, on the other hand, integrative policy development with the ministry involved should receive attention.
2. *Firm up on data and statistics.* The poor state of statistics has many aspects. Data is not correctly captured, collated and published, discrepancies are not questioned or cannot be explained, and data is often quoted without interpretation or context. A strategy is required to develop a set of reliable and useful statistics that allows for national policy development and decision making. An activity-based freight flow model for the country, building on the UFFM, will go a long way towards solving this problem. Importantly, this model should have a 30 year forecast component.
3. *Data-driven joint strategy development.* Policy makers should involve all stakeholders in development discussions, based on analysed statistics, to inform decision making. There are many suggestions on how to improve the freight-flow landscape, but a rough analysis points to different priorities for improvement. As an example, streamlining border crossings and the development of a domestic logistics industry that can work across borders are often mentioned, but improving clustering and developing a regional intermodal strategy might be more important.
4. *Consolidation centres that are local- and region-critical.* Little evidence could be found that the positioning and design of the current SEZs will be optimal. This can only be determined by a freight-flow and related cost model. Evidence from other countries point towards this being one of the most important spatial and logistics strategies and should be informed by more in-depth freight-flow analysis and forecasts.
5. *Insert rail effectively into domestic and regional supply chains.* This relates to linkages with SEZs, design of the SEZs, rail's role in regional intermodal and the efficiency of the railway itself.
6. *Become more effectively involved in a regional freight-flow, clustering and intermodal strategy.* Leadership in evidence-gathering (both from other nations and through proper development of its own statistics) will allow Uzbekistan to take a lead in a Central Asia freight strategy. Maritime nations have the advantage of a highly efficient, global water-based trade system. Uzbekistan's inordinate reliance on surface freight is a big risk.
7. *Develop a logistics strategy that specifically concentrates on the Western portion of the country.* Development ideals for the West must be confirmed and strengthened. This should be forecasted in terms of freight flows to align logistics strategies with freight flows.

## 9 Concluding remarks

The four overarching macrologistics challenges identified in Uzbekistan with the aid of the UFFM are:

- High demand for transport and logistics services relative to economic output;
- High logistics costs compared to other emerging economies;
- High exposure to logistics inefficiency outside of the country, i.e. where the country cannot directly influence improvements; and
- A crippling lack of aligned, generally accepted decision-making data and tools to address these challenges (refer Annexure A).

The concept UFFM is the starting point of a macrologistics decision-making tool and can be refined with access to outstanding data sources. Further refinement is advised to aid more detailed industry and regional analysis and scenario development for the identification of priorities to address modal, spatial and regional integration challenges which, in turn, will improve logistics costs and support the shift from fragmented to integrated multimodal planning.

## 10 Acknowledgements

The authors would like to thank The World Bank for funding this research.

## 11 Annexure A – Comparison between UFFM outputs and available data on freight flows in Uzbekistan

Numerous reports on Uzbekistan's freight logistics environment quote disparate and unverified data on freight activity, pointing to the following challenges:

- Data sources differ and sometimes even the same source provides dissimilar data;
- The data is quoted without context or verification;
- The data time series is illogical and 'breaks' in time series are not explained;
- Commentary on the significance of the observations is lacking, e.g. is it high, low or average?
- The link between observations and proposed strategies is not provided.

A large amount of input data does exist within Uzbekistan to create a reasonably solid platform from which a freight-flow model can be created, but unwillingness to share was encountered. The outputs of the best possible concept model that could be created are reflected above and illustrations of how to use the outputs in data-driven planning are provided.

### 11.1 Identification of challenges with available data sources

Available statistics reflect tonnes shipped by road as about 1.4 billion tonnes (although an alternative time series that gives just over a billion tonnes also exists) and 68 million tonnes on rail, compared to the UFFM output of 195mt (refer Figure 17). Apart from the differences in statistics and the break in the time series, an analysis of Uzbekistan's economy indicates a GDP 'weight' of less than 200 million tonnes. The available statistics would therefore imply that everything in the country, on average, is shipped 5 or 6 times, which is highly unlikely. And even at 200 million tonnes of freight Uzbekistan's GDP is worth only $150 per ton, compared to for example $410 per tonne for South Africa and $559 per tonne for India. At a billion tonnes of freight that value is reduced to $30 per ton, which does not make economic sense.

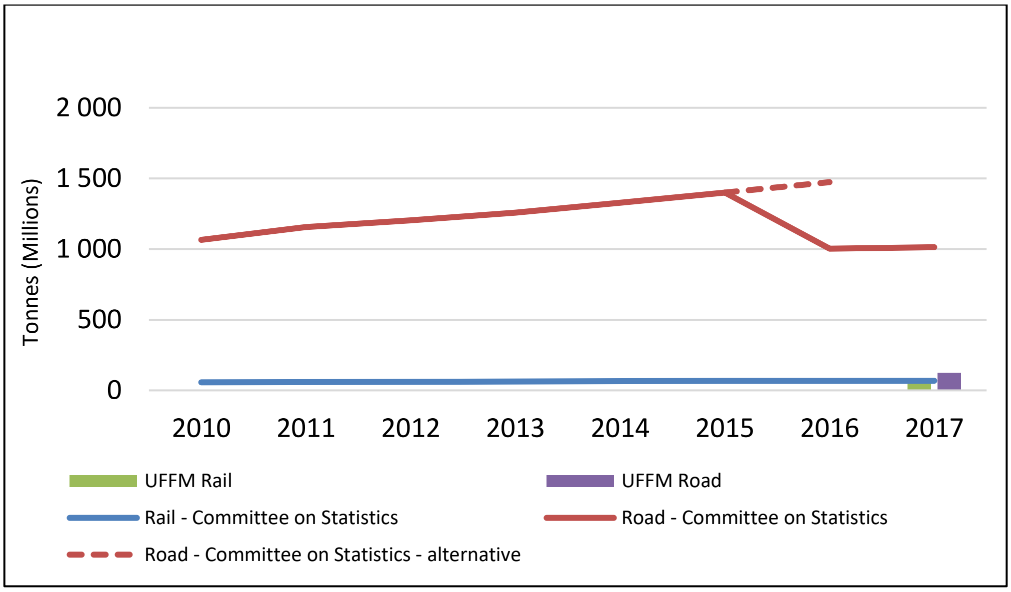


**Figure 21: Tonnes shipped – comparison between available data and UFFM outputs**

A similar picture is evident for tonne-kilometres (refer Figure 18). One source estimates a drop in tonne-kilometres on road from 32 billion to 14 billion tonne-kilometres between 2015 and 2016, and another source reports 36 billion tonne-kilometres. The UFFM estimate is around 40 billion tonne-kilometres on road.

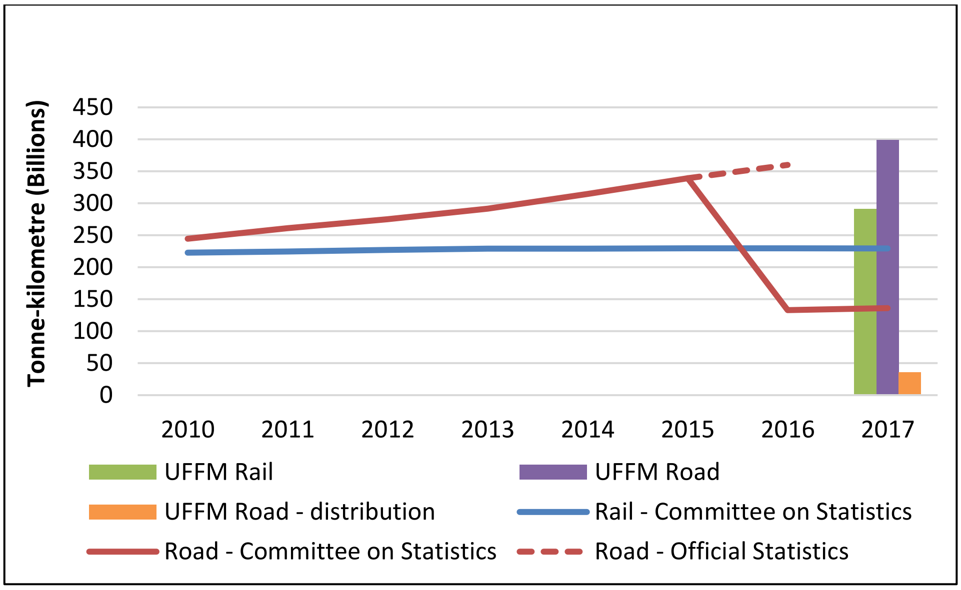


**Figure 22: Tonne-kilometres – comparison between available data and UFFM outputs**

The drop in tonne-kilometre will obviously reflect in a drop in average transport distance (refer Figure 19). A drop in both rail and road average transport distance of this magnitude is however highly unlikely, if not impossible, and an average transport distance for road of 13 km just as unlikely. The UFFM estimates an average road transport distance for road line haul of around 320 km.

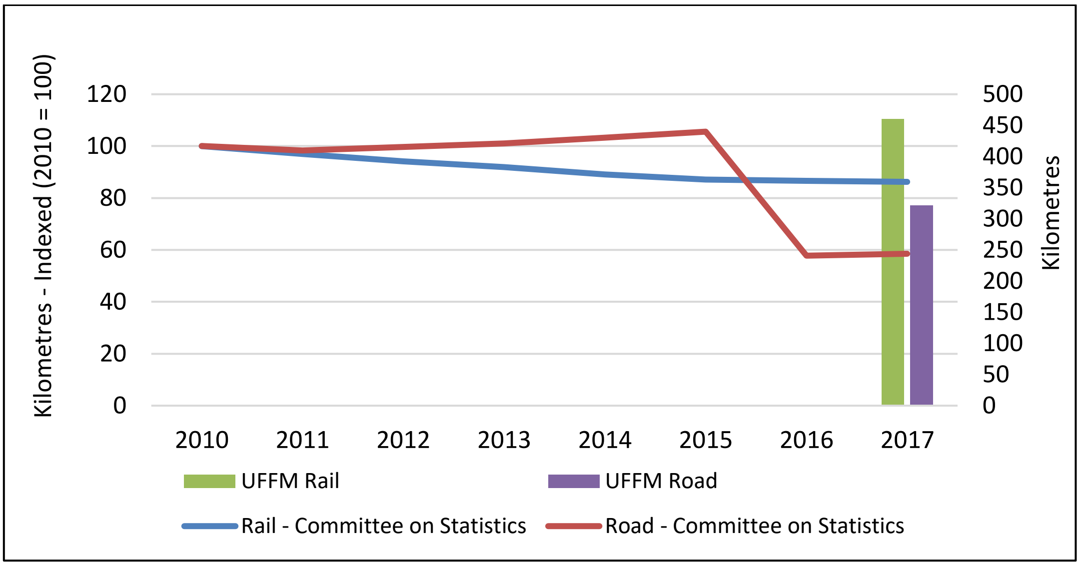


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**Figure 23: Average transport distance – comparison between available data and UFFM outputs**

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## 3.4 Summary: Data-driven macrologistics policy formulation and investment prioritisation in support of macroeconomic goals

The publications included in this chapter succeeded in meeting the following research objectives:

RO3: Illustrating the utility of the outputs from the DNFDMs through application in:

RO3.1: Data-driven macrologistics policy formulation and investment prioritisation in support of macroeconomic goals

It is important to note that it is the detailed spatial and commodity disaggregation in the DNFDMs that enable the varied analyses required to propose the data-driven policies presented in this chapter. This facilitates detailed segmentation coding to inform spatial, modal and sectoral strategies from 'first principles' – it is therefore not generic strategies, but strategies embedded in data that can be interrogated by stakeholders for validity, refinement, targeting, and planning.

In the case of South Africa, the results highlight that the country requires a threefold focus in freight-flow optimisation: (1) in terms of volume to continue leveraging the country's natural endowment of and infrastructure investments in bulk mining exports, (2) in terms of value in order to increase the competitiveness of current domestic and export flows and to enable further local beneficiation opportunities to stimulate inclusive economic growth and employment and (3) in terms of access to increase the participation of the rural economy, with a priority area the revitalisation of branch lines. Investing in three intermodal hubs in the major metropolitan areas of Gauteng, Cape Town, and Durban aswell as the implementation of domestic intermodal solutions on the country's two most dense general freight corridors, Gauteng-Cape Town and Gauteng-Durban (more than half of South Africa's potential intermodal freight moves on these two corridors) will reduce both domestic and international trade transport costs and externality costs. This, in turn, will improve the competitiveness of domestic and international freight, while reducing the environmental impact of transport. Rail branch line densification will improve market access for rural economies and reduce logistics costs while alleviating poverty because of its potential impact on rural development and improved spatial planning, currently hampered by excessive urbanisation.

The outputs of India's DNFDM confirmed the dense, quadrilateral concentration of freight on the corridors connecting the country's four major metropolitan areas of New Delhi, Kolkata, Chennai and Mumbai. More than two thirds of tonne-kms in India are delivered by road transport, with road average transport distances exceeding that of rail. There is a sizeable opportunity for modal optimisation, especially on the long-distance corridors. The disaggregated nature of the DNFDM enabled the development of strategies to support the country's Dedicated Freight Corridor (DFC) initiative in India, with a priority focus on the country's most dense corridor, the Eastern Corridor between Kolkata and Delhi. The analyses resulted in an integrated proposal for an extended gate for the port of Kolkata and a logistics hub outside of Kolkata with a high-volume link into the city, showing potential to reduce transport cost on the corridor by 14%.

Uzbekistan's in-process political and economic transition from authoritarian rule in 2016, and its need to play a proactive role in its positioning in Central Asia and China's Belt and Road Initiative, necessitated an explicit, shared understanding of its economic structure and resulting national logistics needs and priorities, in order to leverage opportunities for connectivity created by this shifting geopolitical landscape. The three objectives of the Uzbekistan freight-flow model was (1) to support the development of Special Economic Zones (SEZ's), (2) point to rail utilisation and improvement opportunities and (3) inform the development of a transport strategy for Uzbekistan. All three these objectives were reached. The outputs highlighted that the planned placing of SEZs serves only 5% of current freight, whereas optimal locations informed by the DNFDM can reach 10%-20% of freight. The explicit consideration of intermodal solutions, and optimising rail linkages with the SEZs, inform improved utilisation of rail. The model also highlighted that more than half of Uzbekistan's transport volumes and costs originate outside of the country, with high dependence on international operators. This places significant risks on the country's logistics costs and on its macrologistics sovereignty. These three elements will form the core of a macrologistics strategy for Uzbekistan and, if leveraged, enable the country to take a lead in a regional logistics strategy. The country has the potential to be the Singapore of Central Asia, but requires work in regional cooperation, modal shift and hub formation. The model assisted with recommendations in all of these cases.

In closing, it is important to emphasise the value of the grounded theory principles to freight demand modelling (refer Section 1.3). As discussed in the published article and book chapter in Chapter 2, South Africa had a relative wealth of data with comparative ease of access on which to base the country's DNFDM; even for disaggregation, secondary keys are comparatively readily available – the major data hurdle was coding all the input data into the regions and commodity groups in DNFDM. India has a large bureaucracy where a wealth of data is captured. However, there is little visibility of this data, and data is not coded or captured for decision-making. Stakeholders were also initially very reluctant to share data, possibly a remnant of the country's colonial history. In the case of Uzbekistan, there are significant data challenges, where some requested datasets could not be obtained prior to the finalisation of the model – the process of supply and demand matrices population and related assumptions have been discussed in Section 3.3. It confirms that DNFDMs can initially be credibly developed with limited input data, however, as the application possibilities of the DNFDM outputs are being shared more widely, there is a growing appreciation of the importance of this work, as was the case in both India and Uzbekistan. A virtuous cycle therefore emerged — high-level quantification is developed with little data to inform responses to pressing questions in the logistics landscape. This leads to buy-in and increased participation by users, facilitating access to data and the quantification of more pertinent questions and scenarios to facilitate macrologistics planning and decision-making – confirmation of the grounded theory approach.

The research presented so far in this dissertation established the methodology to develop freight-flow models with hybrid input data and illustrated how the outputs of these models are used for data-driven macrologistics policy formulation and investment prioritisation. National (such as for South Africa, India and Uzbekistan) and regional macrologistics strategies (such as for the Eastern Corridor of India) are possible. The next objective is to determine whether macrologistics solutions for a specific value chain, or a logistics technology serving a specific value chain, could be enhanced with freight flow modelling. To that purpose a DNFDM for Mongolia was developed and applied to inform the development of Mongolia's meat value chain, and the South African DNFDM outputs were used to focus on a major shortcoming in the South African logistics landscape, i.e. domestic intermodal solutions for the fast-moving consumer goods (FMCG) industry.

# Chapter 4. Applying model outputs: Re-imagining macrologistics value chain development

This chapter addresses the following research objective:

RO3: Illustrating the utility of the outputs from the DNFDMs through application in:

RO3.2: Re-imagining macrologistics value chain development

This chapter consists of four sections. Section 4.1 positions the chapter within the narrative of the dissertation. Sections 4.2 and 4.3 contain unpublished, which comprise the primary part of this chapter, discussing the application of DNFDM outputs to re-imagine macrologistics value chain development. Finally, Section 4.4 is a combined summary of the two publications, highlighting the value chain possibilities that can be unlocked due to the availability of DNFDMs.

## 4.1 Introduction

In the previous chapters the rationale for an explicit focus on macrologistics was established, the methodology for developing DNFDMs in emerging economies was described and the utility of the DNFDM outputs was illustrated through application in data-driven macrologistics policy formulation and investment prioritisation in support of macroeconomic goals. In this chapter, the objective is to investigate the potential of utilising DNFDM outputs to inform value chain development in emerging economies.

In Section 4.2, a case study is presented leveraging value chain analysis and outputs from the DNFDM for Mongolia[12] to facilitate targeted infrastructure investment planning. The rationale for incorporating a value chain view is that uncoordinated infrastructure investments lead to suboptimal investment decisions, resulting in an inability to extract the inherent value in the chain. The article provides an overview of the evolution of value chain concepts from the firm level to the national level; the impact of infrastructure investment on economic development; and provides examples of successes and challenges in livestock value chains around the globe. The focus then turns to the sizeable livestock sector in Mongolia, with large growth potential, that however does not produce significant value for the smallholder nor the economy as a whole. Through combining strategic value chain analysis and the outputs from Mongolia's DNFDM, the article describes a process to enhance selectivity in infrastructure investment decision-making to potentially unlock value in the livestock value chain.

In Section 4.3, the sizable opportunity for intermodal services – a value chain technology – in the FMCG sector in South Africa is juxtaposed against the critical success factors for translating this opportunity to a sustainable intermodal solution (mentioned in Sections 2.2 and 3.2 as a key element of South Africa's macrologistics strategy). A literature survey highlights the structure of the FMCG sector, characteristics of the FMCG supply chain that results in specific expectations from service providers, and the resulting implications for a rail service provider. Two service delivery options for rail's involvement are discussed. While modal shift is considered on a high level, important challenges such as transit times, cost factors, rail gauge and service dimension are not considered in this paper, but would be required for implementation.

[12] The development of Mongolia's DNFDM follows the same approach as South Africa, India and Uzbekistan (refer Sections 2.3 and 3.3), and is not discussed in the article as that was not the main objective of the article.

## 4.2 Article ready for submission: "Value chain analysis for infrastructure investment planning – The case of the Mongolian livestock value chain"

The article included in this section is ready for submission, once decided on the most suitable journal[13]. The various journals considered, have a particular emphasis on publications relating to the integration and harmonisation of transport system to improve transport system efficiency and environmental impact.

[13] This article was co-authored by Simpson, Z.P., Aritua, B., Van Dyk, E., Meyer, I., Swarts, S., Van der Merwe, J. and Havenga, J.H. The formal declaration of author contributions, as required for publications included in dissertations by Stellenbosch University, is provided in Appendix A.

**VALUE CHAIN ANALYSIS FOR INFRASTRUCTURE INVESTMENT PLANNING:**

**THE CASE OF THE MONGOLIAN LIVESTOCK VALUE CHAIN**

ABSTRACT

INFRASTRUCTURE INVESTMENT IS A KEY MEANS SUCCESSFULLY UNLOCKING THE FACTORS OF PRODUCTION. HOWEVER, IT OFTEN TAKES PLACE IN AN UNCOORDINATED FASHION, LEADING TO SUBOPTIMAL INVESTMENT DECISIONS AND POOR EXPLORATION OF THE ECONOMIC VALUE. IN DEVELOPING ECONOMIES, THIS COULD BE EVEN MORE PRONOUNCED, SINCE INVESTMENT IS DRIVEN BY OPPORTUNISTIC ECONOMIC EXPLORATION IN THE ABSENCE OF COHERENT POLICIES AND STRATEGIES. MONGOLIA'S LIVESTOCK SECTOR HAS THE POTENTIAL TO UNLOCK APPROXIMATELY USD 800 MILLION OF EXPORT VALUE, IN VIEW OF THE LARGE DEMAND FOR PROTEIN BY ITS IMMEDIATE NEIGHBOR CHINA. HOWEVER, ITS DISTRIBUTED PASTORALIST SECTOR OF LIVESTOCK PRODUCERS POSES SPECIFIC CHALLENGES TO THE REALIZATION OF THIS VALUE IN TERMS OF GEOGRAPHICAL DISTRIBUTION, INDUSTRY SOPHISTICATION, AND VALUE CHAIN STRUCTURE. THIS ARTICLE PROPOSES A NOVEL APPROACH TO INFRASTRUCTURE INVESTMENT DECISION-MAKING, IN WHICH AN ANALYSIS OF MACROLOGISTICS FREIGHT FLOWS ARE COMBINED WITH VALUE CHAIN ANALYSES TO PRIORITIZE INFRASTRUCTURE INVESTMENT FOR ECONOMIC GROWTH. A RECONFIGURED VALUE CHAIN IS PROPOSED, AND THE TRANSPORTATION COSTS AND INFRASTRUCTURE IMPLICATIONS OF THREE DIFFERENT FREIGHT FLOW SCENARIOS ARE PUT FORWARD. THE PROPOSED APPROACH, AS ILLUSTRATED FOR THE MONGOLIAN MEAT VALUE CHAIN, PROVIDES GOVERNMENTS WITH A TOOL TO TAKE A COORDINATED APPROACH TO INFRASTRUCTURE DEVELOPMENT, RATHER THAN TO BE AT THE MERCY OF MARKET FORCES. AS SUCH, GOVERNMENTS ADOPT A CONTROLLING ROLE, AND BECOME THE INVISIBLE HAND THAT FACILITATES ECONOMIC DEVELOPMENT IN THE ABSENCE OF STRONG MARKET FORCES.

KEYWORDS INFRASTRUCTURE INVESTMENT, MACROLOGISTICS, LIVESTOCK VALUE CHAIN, MONGOLIA, DECISION SUPPORT

# 1. INTRODUCTION

In the ongoing quest for economic development, winners and losers are arguably differentiated by their ability to successfully coordinate the factors of production. In developed economies, capital has productively been employed to create an environment in which further investment would enhance competitiveness and growth. On the other hand, many developing economies are struggling to unlock their drivers of growth in a meaningful, sustainable, and integrated manner. Many developing countries are endowed with mineral resources, which if properly exploited, could significantly improve their economic outlook. Infrastructure investment, which is the backbone for natural resources exploitation and one of the most expensive inputs, often takes place in a piecemeal fashion, and growth remains elusive in the face of inefficient investment decisions (e.g., Lenz et. al. [30]; Muller and Zandamela [38]; Turok [62]).

Value chains have long been employed as a construct to facilitate the competitiveness of firms. In the inception of its definition, Porter [47] conceptualized a competitive environment in which firms would benefit, and unlock value, by investing to position themselves optimally in the value chain. An understanding of the levers of value creation, and investment in unlocking such value, would facilitate competitiveness and strengthen the firm's gains in the economy. Examples of successful adoptions of value chain approaches for unlocking value are numerous, and include Unilever, IBM, Cisco Systems, Starbucks, and others (Verwijmeren [66]). The value chain approach enables firms to take a holistic view of areas of weakness and strength, and identify where finite resources need to be targeted to achieve maximum overall impact. These firms are able to take a local, regional, and global view of their market position and make informed decisions. At the national level, these firm-level investments would translate into enhanced economic development. As per Adam Smith's concept of the Invisible Hand (Smith [58]), market forces would facilitate a trickle-down of investment, that would ultimately benefit all.

However, implicit in the above narrative is the assumption that firm value is unlocked within a healthy enabling environment, where the factors of production are employed appropriately, and where investment would indeed have the potential to stimulate further economic development. In the case of many developing economies, this narrative does not hold true.

In rare instances, a structured approach to value chain development has facilitated economic development through the establishment of selected sectors. These approaches have shifted the burden of control from the enabling environment of the economy as Invisible Hand to that of the state. For example, in the aftermath of the First World War and the 1933 Depression, an entire industrial value chain was developed in South Africa through the establishment of state-supported enterprises to extract its natural resources to provide affordable energy, establish steel manufacturing capabilities, and develop military and marine manufacturing industries (Mawere [33]; Schonland [54]). Similarly, the coordinated post-World War II efforts of the German government facilitated the establishment of a successful manufacturing industry (Godart and Görg [13]). At the time, the concept of a value chain was of course undefined, and its exploration in the structured development of an economy was not explicitly adopted.

In the current environment, developing economies are struggling to achieve the economic advances that are required to support growth. Global value chains, now accounting for more than two-thirds of global trade, offer opportunities for countries to increase income and create employment (UNDP&WEF [64]). However, successful participation in global value chains requires reliable infrastructure, efficient processes at borders, fast and accurate information transfer, and low transaction costs (Luo and Xu [32]; World Bank [71]). Analysis shows that countries with poor logistics performance are not central to global value chains (World Bank et al., 2017). This inadequate performance could partly be ascribed to their inability to facilitate a structured, integrated approach to infrastructure development (Lenz et. al. [30]; Muller and Zandamela [38]). Economic development that is left to its own devices by a struggling economy, as opposed to appropriate facilitation of coordinated decision-making by the state, is of concern.

The success with which firm-level value chain development has been adopted for increased competitiveness begs the question as to whether this approach could be extended to facilitate improved competitiveness at the national level. We postulate that the value chain could be employed as a construct to facilitate national-level infrastructure decision-making to guide the establishment of the factors and enablers of production. Where infrastructure decision-making is guided by the construction of a competitive value chain, decision-making is directed and economic impact can be designed for.

This article contributes to the literature by exploring the development of competitive national value chains as a means of guiding infrastructure development decisions, based on the Mongolian livestock value chain as case study. Mongolia has access to the rich, but unexplored, resource of livestock husbandry as a factor of production and potential driver of economic growth. This pastoralist meat producing sector is considered as a fertile ground for unlocking significant value and is explored as a case study to illustrate the application of value chain approaches for economic development.

The remainder of this document is structured as follows. Section 2 provides an overview of the role of value chains in infrastructure investment, while Section 3 describes the context of smallholder livestock value chains in development. Section 4 outlines how a value chain approach is used to unlock value in the Mongolian meat sector, and Section 5 generalizes the concepts for application in other industries. Section 6 concludes.

## 1. THEORETICAL BACKGROUND: VALUE CHAINS AND INFRASTRUCTURE INVESTMENT

Kaplinsky and Morris [28] position value chain analysis as both a heuristic (descriptive) device and analytical tool, which is in the latter capacity able to provide insights into global income distribution and "the identification of effective policy levers to ameliorate trends towards equalization." (Kaplinsky and Morris, [28]). They proceed to position value chain research as a means of understanding and mitigating the inequalities that are brought about by globalization (Kaplinsky and Morris [28]). In this review, we explore value chain analysis beyond the traditional definition of Porter [47] and focus on its potential application as a means of enhancing national competitiveness through infrastructure development.

### 1.1What are value chains?

The value chain concept was first introduced and popularized by Michael Porter in 1985 (Porter [47]) and enhanced by other authors. Porter's definition has a strong focus on value-adding activities, as follows:

*"The value chain is defined as the linkage between multiple firms' supply chains, i.e. the set of distinct physical and technological value adding activities performed by these economic actors to create the product or service acquired by the customer"* (Porter [47]), Christopher, [8]).

Kaplinsky and Morris put forward a similar perspective, but with a focus on input, process, and output activities:

"The value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumer, and final disposal after use." (Kaplinsky & Morris [28]).

In considering a livestock-specific food value chain, the FAO [9] proposes the following:

"The full range of people and organizations and their coordinated value-adding activities that produce and transform livestock products that are sold to final consumers in a manner that is profitable throughout, has broad-based benefits for society, and shows neutral or positive impacts on natural resources. It fully considers the interaction between its components, and the physical, social, and economic enabling environment".

While the definitions of value chains are numerous, the adoption of any definition should be guided by its intended use. Some value chain definitions, as related to their use, are summarized in Table 1 below:

| **Focus** | **Use of definition** | **Characteristics** | **Reference** |
|---|---|---|---|
| Firm within value chain | Enhance the competitive position of the firm in the chain | Focuses on organizational activities<br>Evaluates value added by each activity to organization's products or services | Porter [47]<br>Christopher [8] |
| Value chains in their sectoral and global contexts | Use value chain research as a means of understanding and mitigating the inequalities that result from globalization | Value chain as:<br>a description (heuristic)<br>an explanation: why a specific form (analytical)<br>Learn and upgrade to participate in global markets<br>Understand the determinants of income distribution | Kaplinsky and Morris [28] |
| Chain within its enabling environment | Enhance the competitiveness of the entire chain by strengthening the enabling and supporting actors. | Consider the following when donors are intervening in value chains:<br>Value chain players<br>Value chain supporters | Roduner [49]<br>FAO [13] |

| | | | |
|---|---|---|---|
| | | Value chain influencers | |
| National value chains | Adopt the concept of macrologistics and national value chains to optimize national approaches to value chain development | Quantitative methods to enable logistics decision-making at a national scale (e.g., infrastructure investment) | Gleisner and Femerling [17]<br>Havenga [22] |

Table 1: Value chain definitions related to their use

Source: Authors

The level at which flows in the chain are considered translates into the focus and nature of interventions – for example, macro freight flows for an understanding of policy-making at the national level (Havenga et al. [18]), sector-level flows for informing sector-level interventions of the enabling environment within which a sector functions (e.g., Roduner [49]), or firm-level flows for optimizing the chain within which a specific commodity flows from origin to destination. Further, the definition could be selected in accordance with a goal of enhancing the functioning of the entire chain (e.g., taking a value creation perspective and optimizing activities to ensure better collective value creation and/ or lower costs), or enhancing the position of a specific role player in the chain (e.g., considering the chain from the perspective of power relations in creating value and seeking rents, so as to influence these aspects between firms). This article adds to existing perspectives on value chains by employing the value chain construct at a national level, so as to design improved national freight flows for increased national competitiveness.

## 1.2 Value chains as an enabler for the development of national economies

Porter [47] proposed the first definition of a value chain, by considering the organization as a static set of processes and primary and secondary activities through which the flow of goods was managed. The concept was defined in the paradigm of understanding how activities contributed to value creation, and how that value facilitates superior competitiveness for the firm under consideration (Porter [47]).

The firm-level application of Porter's model would improve competitiveness by determining how the firm could invest in value-creating activities along the value chain, with the purpose of enhancing its value proposition.

This focus on competitiveness relates to the context within which value chains were first defined and used as an analytic construct: it was implicitly assumed that business was conducted in an enabling environment where competitiveness was possible, and where the focus was on competitively advancing economic value, rather than on creating an environment within which some economic value can be created.

Regardless of this implicitly assumed competitive and developed context of the initial definition, the concept of a value chain has since its inception often been adopted as a thinking tool in the facilitation of economic development. Roduner [49] explores value chains as an enabler of economic development and highlights three value chain constructs in addition to the value-addition focus proposed by Porter, namely: (1) The

French *"filiere"* concept, where goods flow in "a static model of non-changing actors and national boundaries"; (2) *global commodity chains*, where the focus is on power relationships in the chain; and (3) the *world economic triangle*, where a "combination of strong local linkages within global commodity chains might bring upgrading prospects for regions in developing countries".

In the application of value chains to development, the original context of competition and power relations in the chain are retained, while development is facilitated by adopting value chains as a means of connecting the "developing" and the "developed", and as such facilitating benefits in the developing economy.

In defining and applying value chain constructs, the contrast between Porter's original intent of value creation in a developed context, and the realities of an underdeveloped context, is not considered. Further, the appropriateness and role of the construct is not explored in relation to the extent of development that is pursued in the developing environment under consideration. Specifically, the nuances of application in extremely underdeveloped contexts, relative to the modern and industrialized context within which Porter defined and applied the construct, is not contemplated.

Rethinking the role of the value chain in economic development presents possibilities for formulating appropriate development programs and policies (Roduner [49]), and for the practical enhancement of value chain functioning. For example, the FAO's [13] Sustainable Food Value Chain (SFVC) framework is a practical tool for developing sustainable value chains for small-scale livestock farmers. The SFVC framework emphasizes the importance of the enabling environment such as the distance to consumers, the presence or absence of logistics infrastructure (markets, road, rail, etc.), legislation and policies, and sociocultural aspects. Saarelainen and Sievers [52] suggest combining a local economic development approach with value chain development to improve the understanding of the local context such as cultural norms and behavior, market systems, and constraints to infrastructure development.

Despite the above applications, the fundamental merit of the value chain as a construct to unlock national economic value in underdeveloped contexts has not been explored extensively. While some formulations place value chains in the context of their enabling environments (e.g., FAO [13]; (Roduner [49]), the analysis remains guided by an implicit connection to, and benefit from, a developed context.

This reality may be different in extremely undeveloped contexts, where infrastructure is sparse and unaligned with economic priorities, where established sectors with strong actors to drive competitiveness and its benefits are absent, and where significant barriers exist to benefiting from integration with developed contexts.

The integration of Porter's focus on competitiveness at the firm level (Porter [47]) within an assumed enabling environment, with a view on national value chains (Havenga [22]), leads towards the potential application of Porter's model in the context of improving national competitiveness. This could address the current limitations of the application of value chain concepts for economic development.

Infrastructure, as a key enabler of the factors of production, is often developed in an ad-hoc manner that is dependent on private economic interests. While this may lead to optimal exploitation of resources from the perspective of the investor, it may not contribute to optimal and sustainable development of infrastructure from the national perspective.

We propose that the concept of value chains is used as an essential and novel means of supporting infrastructure decision-making to guide the establishment of the factors and enablers of production. The latter, rather than competitiveness, serves as a basis for ongoing value creation. Where infrastructure decisions are made independent of an overall perspective on its role in the value chain, we postulate that its impact on economic performance will remain guarded. However, where infrastructure decision-making is guided by the construction of a competitive value chain, the focus is directed and the economic impact can be designed for.

## 1.3 Infrastructure for development

Literature has paid significant attention to transport infrastructure investment in developing countries, with many studies confirming the contribution thereof to economic growth and structural transformation (Berg, et al. [7]; Setboornsarng [57]). However, a complex relationship exists between infrastructure and growth (Fay and Rozenberg [12]) with a strong dependency of trade on the transport network: better networks are associated with reduced transport cost and improved market access, which in turn leads to improved trade. Similarly, agricultural production could be stimulated by better access to towns and markets; however, such improved access could also attract workers to other labor markets, and thus away from agriculture (Berg, et al. [7]). Limao and Venables [31] estimated a 12 percent increase in transport cost if infrastructure deteriorated from the median to the 75th percentile, and a 17 percent decrease if infrastructure improved to the 25th percentile; further, halving the transport cost (from the median value) would increase trade volumes by 42 percent.

Transport corridors, which could include roads, railways, and access to ports, and allow the flow of people and goods along the route, can be developed to increase trade within a region or to facilitate exports. Transport corridors are especially beneficial for stimulating trade with landlocked countries (OECD/WTO [45]). The Inter-American Development Bank highlighted the important contribution of transport networks and efficient logistics towards reducing trade costs and increasing competitiveness. Delays in the movement of goods increase the cost to the final consumer and reduce competitiveness (OECD/ WTO [45]).

Transport infrastructure could be a necessary condition for poverty reduction, but is not sufficient; it could exacerbate existing inequities. While larger farmers with their own transport could benefit immediately from better roads, small farmers often need assistance to coordinate bulk buying of inputs and joint marketing of outputs (Setboornsarng, [57]). Rural feeder roads are considered to be pro-poor, but the cost to the environment need to be considered (including loss of biodiversity and deforestation). Infrastructure development is costly, and this cost is exacerbated by non-competitive procurement and corruption in developing countries (Berg, et al. [7]). As a result, a network of paths and tracks may sometimes be more effective than roads; further, low-class roads contribute more to rural poverty reduction, while high-class roads generate higher returns to GDP (Setboornsarng [57]).

Agricultural development projects often focus mainly on improving smallholders' production without paying much attention to market linkages, although market access could improve livelihoods and alleviate poverty (FAO [13]). On the other hand, infrastructure development is not always aligned with the needs of the value chains that will use it. The Asian Development Bank [4] identified nine criteria that are essential for the development of pro-poor agricultural value chains. These include the "provision of rural infrastructure that reduces postharvest losses and transport costs, and shortens transit time, while increasing overall rural mobility". Roads should link agricultural production areas with strategic markets while the locations of storage facilities and markets influence the success of the value chain (Asian Development Bank [4]). Analysis showed that better access to transportation, information, and water is associated with a higher income from livestock sales (Meurs et al. [34]).

Straub [59] conducted a literature survey of research on the economics of infrastructure in developing countries. Approximately two-thirds of the reviewed studies identified a significant positive link between infrastructure investment and growth. However, no conclusions could be drawn about the desired levels of spending at different levels of development. The most common way to evaluate the success of infrastructure spending is to calculate the economic rate of return. Average returns of 30–40 percent were obtained for telecommunications, 40 percent for electricity generation, and 80 percent for road investment projects (Estache [11]). Returns showed a tendency to be higher in low-income countries than in middle-income countries.

Finally, ongoing development of the concept of macrologistics, and consideration of the macroeconomic cost of logistics, facilitates improved competitiveness by providing a means of managing logistics as a national production factor (Havenga [22]).

The case study presented in this article illustrates how the value chain construct can be applied to allow governments and funders to ensure that the factors of production function efficiently. In directing infrastructure development in this manner, an infrastructure footprint in support of economic development can be established for generations to come.

### 1.4 Smallholder livestock value chains

The Mongolian livestock value chain is selected as case study for its potential to unlock value for the Mongolian economy (see Section 3). By way of background, this section presents the challenges of, and limitations to, economic development of smallholder livestock value chains across the globe, and the role of infrastructure decision-making.

Based on the value chain definition of Kaplinsky and Morris (2001), the livestock value chain can be defined as the full range of activities required to bring a product such as live animals, meat, milk, eggs, or skins, through the different phases of production, processing, and delivery to the final consumer, including final disposal after use. It can also be defined as “a market-focused collaboration among different stakeholders who produce and market value-added products” (Rota and Sperandini [51]).

The relative benefits from the livestock value chain to lower-income rural households are significant, although their absolute benefits are smaller than those of higher-income households. This supports the case for livestock as a pro-poor policy instrument (Otte et al [39]; Rota and Sperandini [51]).

The livestock sector contributes about 40 percent of agricultural GDP and represents nearly 1 billion smallholder livestock producers in developing countries (Rota [52]). Pastoralists are considered to be smallholders irrespective of their herd size, as their limited resources constrain their sustainability (FAO [13]). Approximately 34 percent of global human protein consumption and 18 percent of global calories is obtained from livestock (AGA News [5]). It is projected that the world population will be 9.6 billion by 2050, of which 70 percent will be living in cities, and with an average income almost double the current average. This will result in a significant increase in the demand for livestock products, which play an important role in human nutrition, but are usually more expensive than crops (FAO [13]; AGA News [5]; Rota [52]).

Numerous value chain analyses have been performed to identify opportunities for smallholder farmers to increase their income from livestock production (Dube et al. [9]; Dzanja et al. [10]; Novaković [34]; OABS Development [44]; Stür et al.. [60]). In a country such as South Africa, where there is a mature large-scale commercialized beef sector as well as an informal smallholder sector, the focus has been on assisting smallholder beef farmers to integrate into the commercial value chain (OABS Development [44]).

Stür et al. [60] investigates the question "can smallholder livestock production systems in developing countries be transformed to take advantage of the increasing demand for meat or will integrated smallholder systems be replaced by intensive industrial production systems?" Globally, 1 billion poor people depend on livestock production for their livelihoods. Traditionally, cattle are used as an asset that is bought when cash is available and sold when money is needed for a major expense. However, livestock production can help poor rural people in developing countries to transition out of poverty, as was achieved by smallholder farmers in the Ea Kar region of Vietnam who evolved from "traditional cattle keepers" to "market-oriented cattle producers" who could compete successfully with other suppliers in city markets (Stür et al. [60]). Farmers were assisted to grow feed to produce fatter animals. They switched from grazing to stall-feeding, which reduced labor requirements and enabled children to go to school instead of looking after grazing cattle. A cattle development coalition of farmers was formed and facilitated by extension officers. Once farmers were able to produce fatter animals, traders were able to access more profitable urban markets and joined the coalition. The initiative was supported by local government, which realized that the income of smallholder farmers can be increased through cattle development. The coalition was based on mutual respect and compliance with sound partnership principles (Stür et al. [60] ).

Consider, for example, Malawi's agricultural sector, which relies heavily on only three commodities, namely tobacco, tea, and sugar, which account for approximately 90 percent of the total value of production. This makes Malawi's economy and its farming population, of which 90 percent are smallholders, highly vulnerable (Djanza et al. [10]). To reduce farmers' vulnerability and increase their incomes, they need to diversify into other agricultural commodities such as, for example, beef. In the 2008 agriculture and livestock census, Malawi's cattle population was estimated at 900 000, owned mainly by smallholders. Cattle are sold through an informal market, which consists of individuals buying directly from farmers, or a formal market, in which farmers sell to feedlots, butcheries, abattoirs or auctions. There are only a few feedlots, which create a power asymmetry between smallholders and feedlot owners. Many butchers do not have the proper equipment for cutting the meat neatly into different grade cuts and some do not have proper cold room facilities (Djanza et al. [10]). Analysis of the beef value chain showed that it is much more profitable for farmers to fatten the cattle before selling them to feedlots. Farmers would further increase their profits if they had abattoirs and could sell semi-processed beef instead of living animals. However, abattoirs are mostly located in urban centers and are not easily accessible to smallholder farmers. Therefore, the commercial viability of small-scale abattoirs has to be assessed. It was recommended to organize smallholder farmers into associations and cooperatives to access better breeds, feeding systems, veterinary services, and improve marketing (Djanza et al. [10]).

In Eswatini (formerly known as Swaziland) the estimated herd of 700 000 cattle belongs mostly to small-scale farmers. More than half of the herd belongs to subsistence farmers on Swazi Nation Land, characterized by low productivity and high calf mortality. As a result, Eswatini cannot fulfill its local demand or EU quota, for which it earns a premium price (Dube et al. [9]). The SwaziBeef project brought together the beef value chain actors including farmers, butchers, meat processors, input providers, and financial institutions to find ways of improving the quality of livestock and meat products. Innovations included the development of low-cost feed to finish the cattle, and the registration of private companies for farmers, to qualify for loans to build small feedlots. At the end of the project, farmers were obtaining \$600 per animal compared to \$250 - \$350 before the project. It is estimated that the loan can be repaid in approximately three years. The Swazi government is planning to set up an additional 20 similar feedlots and build an abattoir to support them (Dube et al. [9]).

In the Krajina region of Bosnia and Herzegovina, the meat value chain was selected for its growth potential as part of a development project aimed at improving SME competitiveness (Novaković et al. [41]). This meat value chain is characterized by underdeveloped animal production and a decreasing number of livestock. In Bosnia and Herzegovina, livestock farms can be categorized into household (subsistence) farms, small farms and commercial farms. There are very few commercial farms, that is farms with more than 20 cattle or 200 pigs. The domestic beef and pork meat processing industry imports approximately 80 percent of the meat used for processing, owing to the poor quality and high price of local meat. Machinery and other equipment for meat processing and slaughtering as well as raw materials for meat processing such as additives and spices are also imported. Meat and meat products are mainly sold to large supermarkets (Novaković et al. [41]). Some of the issues faced by the industry are the shortage of slaughtering capacity, lack of incinerators for the disposal of animal waste, and the shortage of distributors with suitable vehicles for meat and meat products. There are few agricultural associations and cooperatives and they are often poorly managed and influenced by politics. Recommendations include the construction of more facilities for the fattening of animals to improve animal production. A larger degree of cooperation between role-players, which can be achieved through the formation of associations or similar structures, is required to increase the competitiveness of the meat value chain (Novaković et al. [41]).

The meat value chain has drawn attention because of animal welfare and meat quality concerns. Transporting live animals over long distances for slaughter is very stressful, which impacts their welfare and meat quality. In the EU alone, approximately 365 million cattle, sheep, pigs and horses are transported annually (Gebresenbet and Bosona [16]). Owing to specialization and economies of scale, there is a propensity to reduce the number of abattoirs. However, animal transport can be reduced or avoided by using mobile abattoirs or building small-scale local abattoirs (Gebresenbet and Bosona [16]).

Following a series of food scares in the UK in the 1980s and 1990s, including salmonella, E-coli, and BSE (mad cow disease), food safety laws such as the European Union Regulation (EC) 178/2002 were introduced to protect the public (Food Safety Authority of Ireland [15]; BBC News [6]). These laws require traceability of slaughter animals from birth to finished products, which includes information on country of origin and animal welfare, and helps to control the spread of disease. An integrated approach, including all the role players in the livestock value chain from farm to fork, is required for the effective control of food hazards. Compliance is essential for access to export markets. The Australian meat and livestock marketing and research body, Meat & Livestock Australia, attribute the success of their red meat exports to their traceability and quality assurance programs (MLA [35]). Similarly, Namibia has a Farm Assured Namibian (FAN) meat quality assurance and traceability scheme (Namibian Meat Board [40]).

Based on their experience with development projects, the Asian Development Bank states that the identification of infrastructure requirements is important for the development of agricultural value chains. An analysis of strategic links between production areas and markets should inform the location of storage facilities, rural roads, transport hubs, and markets. In addition, policy, regulatory, and institutional reform is required to address key constraints and create an enabling environment for agricultural value chain development (Asian Development Bank [4]).

## 2. CASE ANALYSIS: DEVELOPMENT OF LIVESTOCK VALUE CHAINS FOR THE MONGOLIAN ECONOMY

Mongolia is a developing economy, and its economic performance lags significantly behind best performers and its immediate neighbors. While its export economy is largely dependent on minerals, it has a vibrant but unexplored meat production sector that mostly provides for domestic consumption. This sector evolved from pastoralist roots and is deeply embedded in the culture of Mongolia. As such, production is based on traditional approaches, and a sophisticated logistics infrastructure does not exist to support its export potential. This provides a significant opportunity for improvement and the application of targeted infrastructure decision-making in support of economic growth.

## 2.1 Mongolia in context

Mongolia is the least densely populated country in the world. With just over 3.2 million people inhabiting a territory of 1.564 million square km (more than six times the size of the United Kingdom and less than a third the population of London), Mongolia has a population density of 2.1 people per square km. About half of the population—some 1.4 million people—live in the capital city Ulaanbaatar. The rest of the population is spread across small urban centers and vast steppes where people herd sheep, goats, horses, cattle, yaks and camels. Currently, there are over 70 million livestock owned, increased from 33 million in 1999 to 44 million in 2009, and raised by 233 000 households, compared with 269 950 in 1999 and 226 650 in 2009. Nearly 26 percent of Mongolian households are traditional nomadic pastoralists whose livelihoods are still vulnerable, with livestock often their only source of income and alternate job opportunities scarce in rural areas (NSO [42]).

Mongolia is landlocked between China and Russia and relies heavily on the relationships with its two powerful neighbors. China is Mongolia’s largest foreign investor and trading partner, with more than 90 percent of Mongolian exports going to China (primarily copper, coal and gold). Mongolia’s high dependence on mining as main economic driver has made the economy highly susceptible to external shocks and contributed to boom-and-bust cycles. The Government of Mongolia (GoM) has therefore prioritized economic diversification and regional development to avoid the impacts of over-dependence on mining. The key development strategies as set out in the Three-Pillar Development Policy of 2018 (IFC [26]) and Mongolia Sustainable Development Vision 2030 (GoM [20]) have the goal to diversify the economy through mainly livestock, agriculture and tourism. Furthermore, the government’s Action Program 2016–2020 (GoM [19]) outlines the promotion of sustainable growth by improving the business and investment environment, supporting infrastructure development and implementing national programs to support food, agriculture, and light industry sectors.

Poor infrastructure connectivity, resulting in underperforming economic corridors, inhibits diversification of the economy and competitiveness of sectors with growth potential. Mongolia's agriculture sector, specifically wool, cashmere and meat, has underperformed relative to the country's comparative advantage. This is partly caused by the underdeveloped economic corridors that link herders and international trade. Difficult access to energy networks together with poor transport connectivity has hindered efficient logistics and storage, resulting in large amounts of waste.

Considering some overarching capabilities on the supply side, the picture is bleak. Comparisons of Global Competitiveness (Table 2), and factors that influence such performance, such as the Ease of Doing Business (Table 3), the Logistics Performance Index (Table 4), and Connectedness (Table 5) illustrate Mongolia’s difficult position compared to its neighbors and the best performers. Mongolia has a young and relatively well-educated population, and therefore the necessary foundation to develop logistics capabilities, provided that the required policy support is available. Connectedness is a challenge in Mongolia, given its spatial and demographic characteristics. Hence, an approach that is highly selective to develop critical infrastructure will improve this important score and could make the country more competitive.

| Country | Overall Rank (out of 141) | Overall Score (out of 100) | Transport Infrastructure Rank (out of 141) | Transport Infrastructure Score (out of 100) |
|---|---|---|---|---|
| Singapore | 1 | 84.8 | 1 | 91.7 |
| China | 28 | 73.9 | 24 | 68.9 |
| Russia | 43 | 66.7 | 49 | 57.7 |
| Mongolia | 102 | 52.6 | 119 | 35.5 |

Table 2: Global Competitiveness Index rank and score – Mongolia vs. best performer and neighbors[55]

Source: Schwab [55]

| Country | Rank (out of 190) | Score (out of 100) |
|---|---|---|
| New Zealand | 1 | 86.59 |
| Russia | 31 | 77.37 |
| China | 46 | 73.64 |
| Mongolia | 74 | 67.74 |

Table 3: Ease of doing Business rank and score – Mongolia vs. best performer and neighbors [71]

Source: World Bank [71]

| Country | Overall Rank | Overall LPI score | Customs Rank Score | | Infrastructure Rank Score | | Logistics Rank Score | |
|---|---|---|---|---|---|---|---|---|
| Germany | 1 | 4.20 | 1 | 4.09 | 1 | 4.37 | 1 | 4.31 |
| China | 26 | 3.61 | 31 | 3.29 | 20 | 3.75 | 27 | 3.59 |
| Russia | 75 | 2.76 | 97 | 2.42 | 61 | 2.78 | 71 | 2.75 |
| Mongolia | 130 | 2.37 | 127 | 2.22 | 135 | 2.10 | 140 | 2.21 |

Table 4: LPI rank and score – Mongolia vs. best performer and neighbors [3]

Source: Arvis et al. [3]

| Country | Rank (out of 169) | Score (out of 100) |
|---|---|---|
| Netherlands | 1 | 93 |
| Russia | 54 | 58 |
| China | 61 | 54 |
| Mongolia | 85 | 46 |

Table 5: Connectedness rank and score – Mongolia vs. best performer and neighbors [3]

Source: Altman et al. [3]

Competitiveness is informed by many factors, of which institutions, infrastructure, and macroeconomic stability are considered important. The discrepancies in performance, as outlined above, is influenced by Mongolia's ability to appropriately employ the factors of production, and to create an enabling environment within which these can be optimally employed. Comparisons with other countries highlight the poor condition of transport infrastructure seen as nearly non-existent compared to the rest of the world. In developed environments, both the presence of the factors of production and the enabling environment is assumed. In Mongolia, these need to be actively developed in a coordinated manner. The country is surrounded by economically advanced competitors, and the inability to fast track its economic performance will exacerbate this inequality– leaving economic growth to the devices of an already underperforming economy is unlikely to lead to significantly improved economic outcomes.

Growth without major investments in infrastructure seems more or less impossible, but funding challenges mean that these investments will have to be highly efficient. It also means borders must be easy to cross which will improve the efficiency of export infrastructure and connectedness for Mongolia.

An analysis of industry sectors revealed that the development of the livestock (meat products) value chain and iron ore beneficiation will provide the largest growth in GDP, and the largest reduction in logistics costs as a percentage of GDP (Table 6).

| Sector | Industry | National Logistics cost as % of GDP, will reduce from 24.7% to: | % GDP growth |
|---|---|---|---|
| Primary | Coal export | 21.9% | 13.8% |
| | Iron ore export | 24.1% | 3.5% |
| Secondary | Meat products | 19.7% | 26.5% |
| | Other animal products | 22.9% | 10.5% |

| | | | |
|---|---|---|---|
| | Direct reduced iron | 20.1% | 31.0% |
| Tertiary | Tourism | 24.6% | 0.4% |
| | Transit traffic | 24.1% | 2.9% |

Table 6: Potential industry sector contribution to GDP growth and reduction in logistics cost

Source: Authors

Further, it is expected that the economic impact of the livestock value chain will have a wider geographical footprint and employment growth than direct reduced iron, and is therefore targeted for further analysis in the following section.

## 2.2 Overview: a challenged industry with potential for improvement

Mongolia's meat industry is an important contributor to food security, with potential as an export contributor. The global demand for meat is rapidly growing and has quadrupled over the past 50 years (Ritchie and Roser [48]). The country borders China, with its growing population and insatiable demand for protein. Further, it is relatively unchallenged in the region – unlike the steel industry, which has made limited progress with a fragmented logistics system against China's dominance.

The meat industry has been under-exploited, and the potential for productivity increases has been well-researched (Munkhdelger [39]; SADC [53]; Altangerel & Yi [1]). It is estimated that Mongolia could earn US$1bn annually from agricultural exports to China (World Bank [71]). However, operationalization of the export potential has been hampered by Mongolia's inability to supply the required quality, quantity, and consistency of product.

The meat industry is unsophisticated and relies on herder households throughout the country as a source of production. Key producer challenges include low productivity, poor animal health, and the perishing of meat in the absence of a cold chain (SADC [53]).

During the socialist era (1921 – 1990), livestock was pooled into collectives and herders were grouped into production teams. The state provided fodder, wells, tractors, transport, and veterinary services to improve productivity, and distributed the production through their network (Meurs et al. [34]). The herders were paid a salary with which they bought their meat, as private production was restricted. This production structure was expensive to maintain and did not lead to the development of sustainable export infrastructure.

After the collapse of socialism, the collectives' assets and livestock were privatized; this forced many herders to return to small-scale production to provide for household needs in the absence of state support. The World Bank estimated that a third of herders lived in poverty in 2018, a vast improvement from 58% in 2010. This can be attributed to an increase in livestock product demand and prices as well as diversification into waged employment (NSO & World Bank [35]). Although wool, hair, and cashmere generate the most income, meat also makes a significant contribution.

Producer cooperatives have been proposed as a way to pool resources to improve herder livelihoods (SADC [53]; World Bank [71]). However, this approach requires supplementary investment in infrastructure by the state or private organizations (Meurs et al. [34]). Although processing companies are willing to engage with producer cooperatives, some herders do not trust the financial capacity of such cooperatives (SADC [53]).

Currently, rural household producers supply meat through local and export value chains (see Figure 1). In the local value chain, merchants serve as intermediaries between the households, small slaughterhouses, and the wholesalers, who supply urban areas. In the export market chain, agents source from herder households to sell on to certified meat processing plants for export.

Although meat production exceeds local demand, the current industry structure cannot produce the quantities and quality required for export markets. Further, a large amount of spoilage occurs in the supply chain.

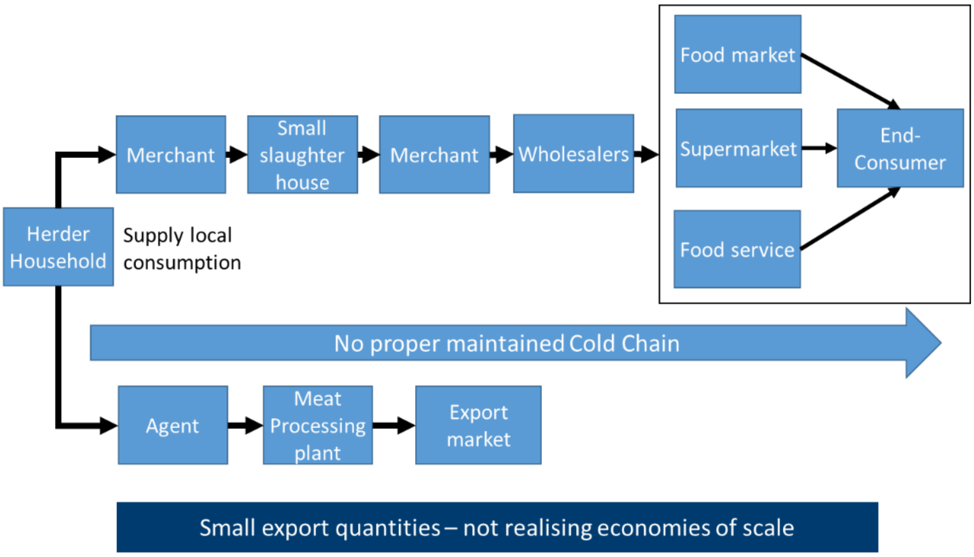



Figure 1: Mongolian meat value chain

Source: Altangerel & Yi [1]

Figure 2 outlines the meat freight flows (the line thickness indicates flow density). The flows indicate that meat is sourced from many locations, and then transported to the capital city Ulaanbaatar through a very inefficient logistics system. Given the long distances and poor infrastructure, most of the meat value is lost along the chain, thus impairing its export value.

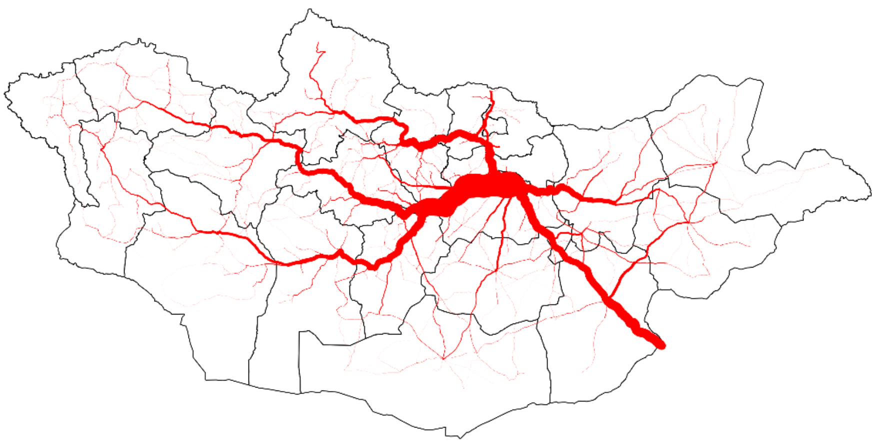


Figure 2: Flow of meat products in Mongolia

Source: Authors

## 2.3 Relative performance

The supply chains of successful meat exporters are structured with the aim to reduce loss of value at each stage from farm to market. For example, the New Zealand and Australian meat sectors have a strong commercial focus and consolidate operations through commercial farming, feedlots, and saleyards. The latter serves as a market mechanism for optimal livestock distribution. The saleyards supply abattoirs with livestock that will yield meat of both domestic and export quality (The Beef Industry [61]).

However, a commercial approach may not be transferrable to sectors that are driven by rural household producers, where cultural and religious considerations, as well as tradition, often dictate the production potential of the sector. In Mongolia, the social structure of herder households and their reliance on their livestock play a significant role in productivity and realization of export potential (Meurs et al. [34])

From a spatial perspective, Mongolia's current challenges are not insurmountable. Other spatially challenged environments have developed working solutions. For example, Namibia has structured its commercial livestock sector around auctions and transporters, which serve as a market mechanism to distribute livestock within the supply chain. This has enabled the country to earn, in addition to its branded FAN organic meat, more than three times more than Mongolia from meat export with nine times less livestock. However, Namibia facilitated the competitiveness of its commercial livestock sector by enabling the factors of production through financial support for livestock purchases, infrastructure development, access to a subsidized marketing system, and provision of expert technical advice (Legal Assistance Centre [29]).

## 2.4 A revised value chain structure

Key points of concern in the current value chain are a lack of control over its supply, as well as losses throughout the supply chain due to poor animal health and carcass spoiling. The proposed meat supply chain in Figure 3 for Mongolia aims to position the sector for high productivity. It comprises consolidation of animal health and processing services and integrates herder households as its cornerstone based on additionality. This approach is deemed to be minimally disruptive to the status quo.

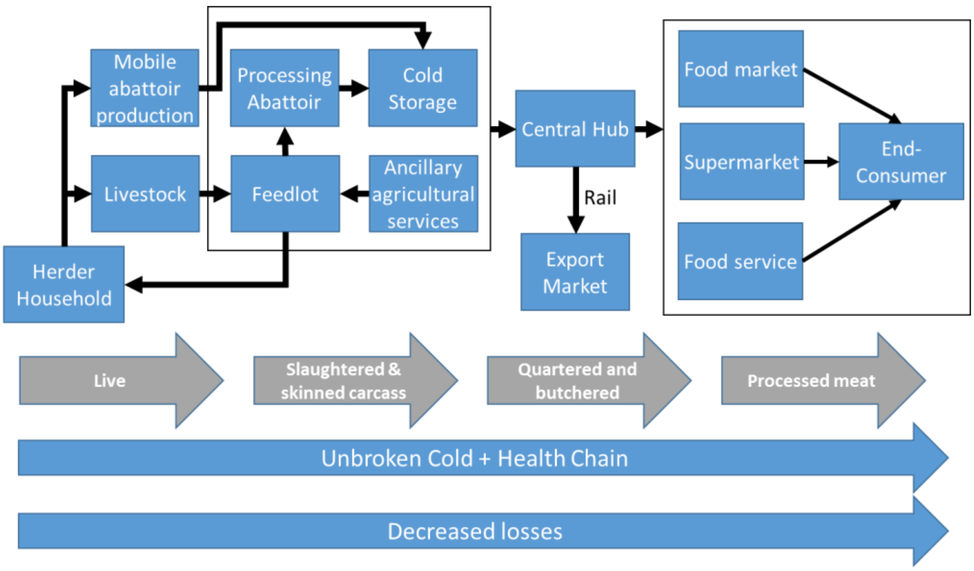



Figure 3: Reconfiguring the Mongolian Meat Supply Chain (Source: Authors)

The proposed supply chain includes mobile abattoirs to reach multiple households and reduces transport by consolidating rural carcass supply. Feedlots are proposed to increase the reliability of livestock supply, mitigate harsh winter conditions, and hence improve the quality of herder households' livestock. Agro-processing freight villages (hubs) will provide veterinary and agricultural support services and will facilitate cold chain maintenance by providing cold storage. Slaughtered carcasses are transported to, and processed at, larger centralized freight villages for export and urban markets.

These additions to infrastructure enable the utilization of animals that would have been unsuitable for inclusion in the value chain. By developing appropriate infrastructure for the meat supply chain, Mongolia can unlock around US$800 million from meat export (World Bank [70]).

## 3.5 Infrastructure investment for improved performance

Following the structural reconfiguration of the value chain as proposed in the previous section, the spatial reconfiguration is considered. This is approached here by analyzing the flow of freight between key points of supply and demand. The freight flow model indicates that the *aimags* (provinces) Uvs, Khövsgöl, Bulgan, Arkhangai, Övörkhangai, Töv, Khentii, and Sükhbaatar are ideal locations for freight villages (hubs) to consolidate the meat market (see Figure 4). These are well aligned with the meat flows, as illustrated in Figure 2. Each *aimag* hub is supplied by the nearest surrounding *soums* (districts) through mobile abattoirs. Three meat transportation scenarios were evaluated. In the first scenario, meat is processed at the hubs for direct export to China. For the other two scenarios, the carcasses are consolidated for optimal transportation to the major hub in Bagakhangai for final processing. The processed meat can then be consolidated in refrigerated containers for export via rail or road. In the second scenario, the meat is exported by rail and in the third scenario by road. Bagakhangai is located approximately 90 kilometers southeast of Ulaanbaatar in the Töv *aimag* and could conceivably become a 'sustainable' city with a highly advanced service and ICT sector.

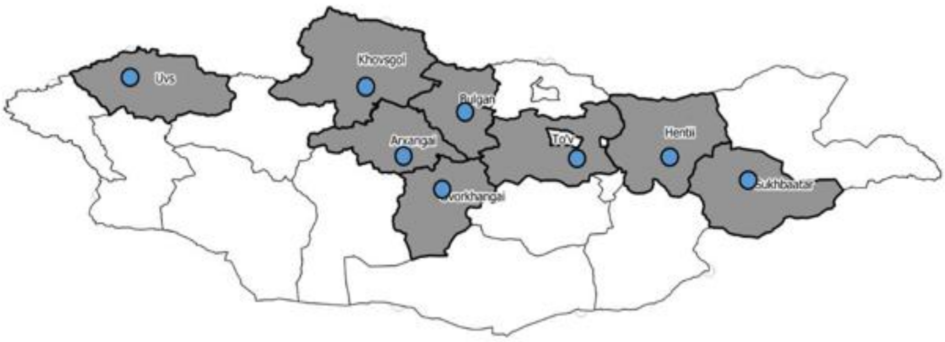



Figure 4: Location of the identified agro-processing freight villages

Table 7: Estimated transportation cost for meat freight flows

Source: Authors

Note: Assumptions: The cost per ton-km from the soums to the hubs - US$0.11; the costs from the hubs to Bagakhangai and the Chinese border - US$0.06; and the rail cost - US$0.02 per ton-km.

Table 7 outlines the estimated transportation cost of meat on different links of the network as described above, as well as the distance of roads that is required to be in good condition. The last row indicates the cost of transporting meat from the consolidation hub to the local market in the capital city.

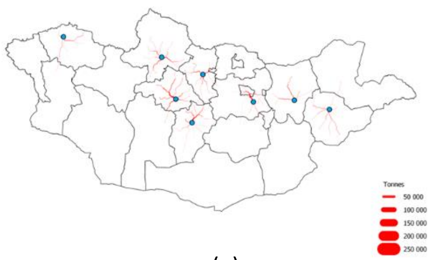
| Meat freight flows | Ton-kms million | US$ Million | Kilometers of good roads required |
|---|---|---|---|
| *Soum* to *aimag* hubs | 32.0 | 3.5 | |
| *Aimag* hubs to China (direct) | 289.8 | 17.4 | 3999 |
| *Aimag* hubs to Bagakhangai | 159.2 | 9.6 | 2954 |
| Bagakhangai to China (rail) | 161.9 | 3.0 | |
| Bagakhangai to China (road) | 152.4 | 9.1 | 574 |
| Hubs to Ulaanbaatar | 162.4 | 9.7 | |

Table 7: Estimated transportation cost for meat freight flows

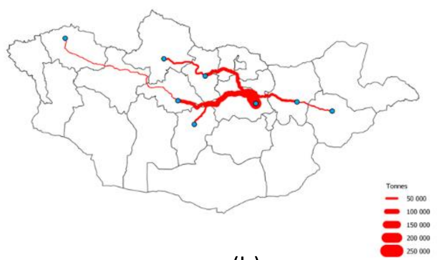
Source: Authors

Note: Assumptions: The cost per ton-km from the *soums* to the hubs - US$0.11; the costs from the hubs to Bagakhangai and the Chinese border - US$0.06; and the rail cost - US$0.02 per ton-km.

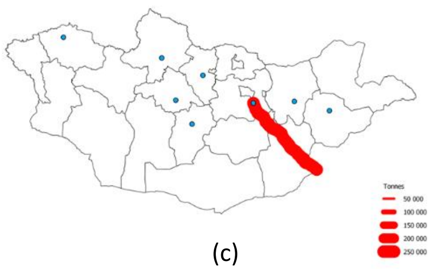
The consolidated meat flows are visualized in Figure 5. Figure 5(a) shows the flows from the *soums* to the *aimag* hubs, 5(b) shows the flows from the *aimag* hubs to Bagakhangai, 5(c) shows the export flows from Bagakhangai to China, and 5(d) shows the combined flows of Figures 5(a), (b), and (c).



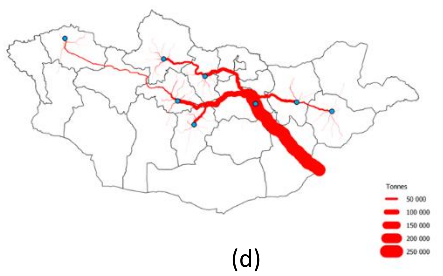

(a)




(b)




(c)




(d)

Figure 5: Typologies of additional meat-processing flows. (a) flows from soums to aimag hubs, (b) flows from aimag hubs to Bagakhangai, (c) export flows from Bagakhangai to China,(d) combined flows of (a), (b), and (c)

Source: Authors

The cost calculations for the three transportation scenarios are summarized in Table 8. The *unconsolidated* scenario requires upgrading and adequate maintenance of 3999 kilometers of roads between the eight hubs and the border, with an estimated transportation cost of US$32.0 million. If meat is exported from the major hub at Bagakhangai by rail, the estimated transportation cost is US$27.2 million, and 2954 kilometers of road need to be maintained adequately between the hubs and Bagakhangai. The consolidation at Bagakhangai with road-based export to China requires 3528 kilometers of good quality roads, with an estimated transportation cost of US$33.3 million.

| **Three transportation scenarios** | **Ton-kms million** | **US$ million** | **Kilometers of roads utilized** |
|---|---|---|---|
| *Soums* to *aimag* hubs to China (direct) | 321.8 | 20.9 | 3999 |
| *Soums* to *aimag* hubs to Bagakhangai to China (rail) | 343.6 | 16.1 | 2954 |
| *Soums* to *aimag* hubs to Bagakhangai to China (road) | 353.1 | 22.2 | 3528 |

Table 8: Estimated transportation cost for three transport scenarios

Source: Authors

The consolidation scenario at Bagakhangai with rail-based export results in the lowest transportation cost as well as the shortest distance of roads to be maintained in good condition – approximately 1000 kilometers less than the *unconsolidated* scenario.

It is estimated that these supply chains require 2,954 km of well-maintained roads as well as rail capacity on the North-South corridor from Bagakhangai to China to operate efficiently. Of the 2,954 km of roads required between hubs, 2,668 km is asphalt concrete. Of the asphalt roads, 105 kilometers are in very good condition, 1,327 km are in a good condition, 1,084 km are in fair condition, and 152 km are in a poor condition. The remaining required road consists of 104 kilometers of cement concrete, 13 km of gravel, 12 km of graded earth, 128 km of ungraded earth road, and 24 kilometers of road that passes Ulaanbaatar to the south. The hubs could be connected to Bagakhangai as shown in Figure 6.

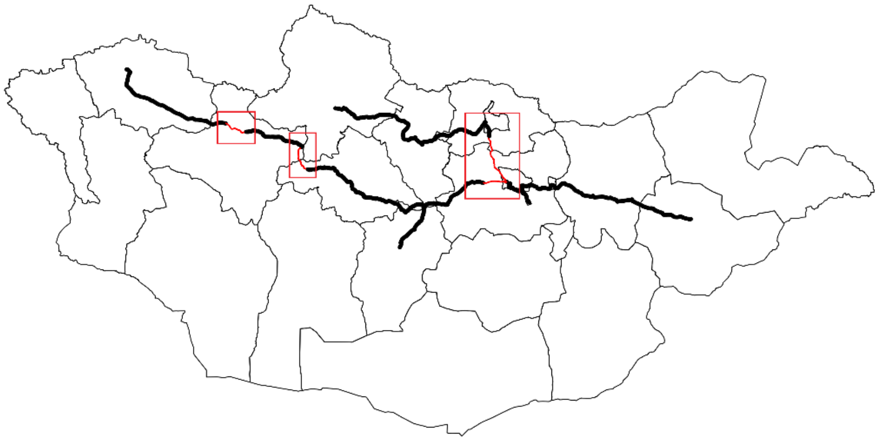


Figure 6: Required road infrastructure to facilitate meat value chain

Source: Authors

The integrated supply chain is outlined in Figure 7. It indicates the physical infrastructure requirements, their specifications, and the soft infrastructure. It is proposed that a globally recognized certification system (for example, branded as "UB1 meat") be adopted to facilitate export market access beyond China and to legitimize the trade through ethical and welfare standards as well as sustainable practices, which protects both the herder households and the animals. The branded meat can be marketed as disease-free, organic, and free-range, in addition to conforming to UB1 standards and practices.

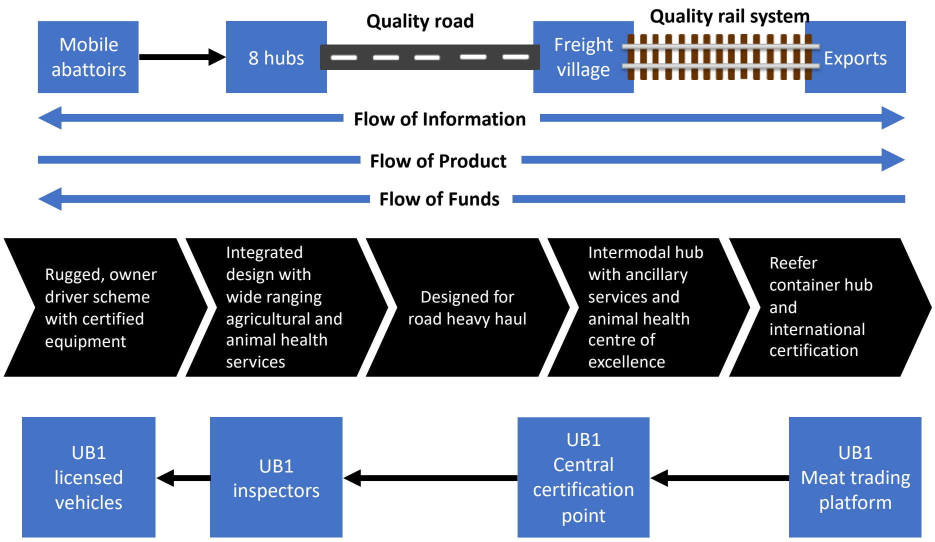



Figure 7: Supply chain design to facilitate the additionality meat scenario

Source: Authors

## 2.6 In summary

The export potential of Mongolia's meat industry is limited by smallholder production practices and approaches, spatial challenges, and a value chain configuration that is not supportive of an export orientation. The reconfiguration of the value chain, and assessment of infrastructure with consideration of freight flows, provide evidence-based support for infrastructure investment that could unlock significant value from Mongolia's meat production sector. It does so with due consideration of local practices while enhancing practice for export gain. Targeted investment in the improvement of specific roads, border posts, and railway lines to enable economic growth by lowering logistics costs and enabling value chain optimization could have a positive disruptive effect in this industry.

# 3 MACROLOGISTICS ANALYSIS AS AN ENABLER OF STRATEGIC INVESTMENT DECISIONS

The Mongolian livestock value chain is characterized by various challenges, as illustrated in the case study. It operates within a developing context and, as such, does not have access to the economic affordances of developed contexts—while natural resources may be abundant, other factors of production are absent, inadequate, or poorly coordinated. In developed environments, the assumption is that market forces and a trickle-down effect will translate the investment of capital for personal gain to benefit for all, as per Adam Smith's metaphor of the Invisible Hand (Smith [58]). However, in underdeveloped contexts, such effects may be too slow, or may not facilitate adequate development to ensure competitiveness.

This case study demonstrated the application of the value chain concept with a view on targeted infrastructure development, so as to unlock the value inherent in a developing context where natural resources are abundant, but the exploitation thereof is inefficient. In the case of Mongolia's meat value chain, this potential amounts to an export value of USD 800 million.

Global livestock value chains are characterized by production units that differ in their level of commercialization and intensification, as well as the sophistication and nature of the markets to which they deliver. For example, in the most unsophisticated cases, rural herdsmen produce in small quantities under extensive conditions for home and community consumption. On the other end of the spectrum, large commercial producers deliver large numbers of animals under intensive conditions, with the know-how to optimize their husbandry and feeding systems for cost-efficiency. In all cases, production units are characterized by their remoteness relative to areas of mass consumption.

Successful global livestock value chains are structured in a manner that delivers the appropriate quality and quantity of product to global markets. Such chains have managed to bridge the divide between rural, localized areas of production and sophisticated and distributed global markets. This implies that products produced in (relatively) small quantities in rural production units over dispersed areas are consolidated, processed, and transported cost-effectively without compromising product quality, while at the same time providing assurances of such quality. Successful livestock value chains include those of Namibia, New Zealand, and Australia. While these countries differ in their balance of production units that are less or more sophisticated and intensive, all have managed to overcome the challenges associated with dispersed rural production to deliver products to sophisticated global markets.

In the case of Mongolia, the potential for economic growth through meat exports is significant. However, its history of herder livestock production and communal consumption has left it lacking in terms of sophisticated livestock industry-focused logistics infrastructure. The industry currently produces mostly for the domestic market and does not have the ability to ensure the delivery of safe food of consistent quality.

The case study illustrated that, through restructuring of the value chain, production could be consolidated, and transport could be coordinated, in a manner that would satisfy the demands of the export market. The introduction of mobile abattoirs and freight villages would facilitate sufficient coordination and value addition to ensure adequate export volume and value. Subsequent modelling of different freight flow scenarios enabled the identification of optimal infrastructure investment to unlock economic value. Further, infrastructure maintenance implications were quantified.

The nature of investments is dictated by both the level of sophistication of existing value chains, and the impact of value chain enhancements on macrologistics freight flows. As such, the proposed approach has two critical elements:

- The identification of targeted investment to unlock specific, quantified economic value in a selected sector; and
- Assessment of the impact of the investment on the national logistics system.

This systemic approach avoids piecemeal, uncoordinated investments, and ensures that the full economic value of the sector can be unlocked. Further, the required investment can be compared with the anticipated economic value. Note that this approach also facilitates a focus on the "soft infrastructure" or enabling environment that is required to unlock value (here, the implementation of an appropriate grading system).

The macroeconomic value chain approach proposed here provides the opportunity to progress towards Mongolia's Vision 2030 and beyond systemically. By considering the potential impact of sector development on economic growth, and by targeting infrastructure investment within each sector to unlock such value by alleviating bottlenecks, the vision of diversified economic growth can be attained in a targeted manner.

The method proposed here aims to enhance selectivity in infrastructure investment decision making by combining strategic value chain analyses and disaggregated flow modelling. The approach can be used to (1) identify infrastructure gaps; (2) prioritize investment needs; (3) diagnose the readiness of the sector to attract private capital; (4) assess benefits and risks of regional corridors; and (5) lay the groundwork for an institutional and financing framework to support the sector. The approach applies to all contexts where infrastructure investment could benefit from a macroeconomic perspective on its impacts.

The method requires access to data in support of macroeconomic freight flow modelling, the status and extent of transport infrastructure, and a clear perspective on the value chains under consideration. The freight demand model is data-intensive and generates a rich dataset of origin-destination freight flows per commodity. While abundant data allows for the best modelling outcomes, even contexts with limited data have sufficient information available to develop guidelines for decision making. The experience of the authors has been that decision-makers contribute more data sources as they realize the model's benefit.

The model requires basic input data that reflects an understanding of production and consumption volumes and locations for the main commodities. While spatially disaggregated data at a commodity level is seldom publicly available, a large amount of useful information is often obtainable from government departments, national statistics offices, as well as rail and port operators. Useful information includes port and border post statistics, customs data, rail data, truck counts, statistics on mining, manufacturing and agricultural production volumes per region, input-output tables per region, and census data. This information is processed into supply and demand for as many commodities and geographical districts as is feasible. As more information becomes available, the accuracy of the model can be refined. In addition to access to data, the approach requires that sufficient analytical skills are available within relevant departments to allow for use of the models and interpretation of results.

While coordination in terms of infrastructure investment decisions varies across economies, it can be expected that more advanced economies are better able to coordinate towards better returns. However, this does not imply that such decisions are sufficiently coordinated to yield maximum returns. Hence, the method proposed in this document has the potential to enhance the return on investment across different contexts, and across developed and developing economies. Implicit to this improvement is the requirement that government departments have the ability to coordinate towards sharing data and adopting model results in support of improved decision making.

However, it should be noted that infrastructure investment on its own is a necessary but insufficient approach to unlocking economic value. Modern development theory promotes participatory approaches to systemic change, with a focus on capability and choice (Kleine [27]; Sen [56]), empowerment (e.g., Grunfeld [21]; Valls [65]), and per-poor (i.e., with the poor) initiatives (Heeks [25]) for sustained impact. In the case of economic sectors with deep cultural ties, such as livestock farming, this is even more relevant, and a holistic approach with multiple concurrent interventions are required to transform a sector for improved economic gain (e.g., Heady et al. [24]; SADC [53]).

## 4 CONCLUSION

This paper introduced a macrologistics approach to national infrastructure investment decision-making, based on the Mongolian livestock value chain as case study.

An analysis of Mongolia's industry sectors showed that the livestock (meat products) value chain has the potential to contribute 26.5 percent to GDP growth and result in a reduction of logistics cost as a percentage of GDP from 24.7 percent to 19.7 percent. However, as the factors of production in this sector are poorly coordinated, the value chain construct was used as a means of analyzing the sector and of providing a focus for infrastructure investment decisions.

By adopting the value chain as a means of analyzing competitiveness, in the manner that many successful firms have done, governments could consider value chains in the context of their macro-logistics systems. This enables them to identify infrastructure gaps and invest in a manner that will support the development of value chains that have significant economic potential.

From a policy perspective, this approach provides governments with a tool to take a coordinated approach to infrastructure development, rather than to be at the mercy of market forces. As such, governments adopt a controlling role and become the Invisible Hand that facilitates economic development in the absence of strong market forces.

This paper puts forward a method based on a single case study in conditions where the benefit to the economy, as well as potential for value addition to how the sector under consideration is structured, is significant. The assertion is that this approach is most beneficial in developing contexts, where the potential for improvement is significant and where the enabling environment is lacking in its ability to support economic growth. In this context, the approach that was followed presumably has the potential to make a significant difference when compared to an approach where infrastructure investment is left to market forces. To better illustrate the value of this approach, it would be beneficial to develop a portfolio of case studies across different contexts. Furthermore, an exploration of related initiatives, other than the quantitative support for infrastructure investment decision-making, is required to ensure that such investment catalyzes sustained change and delivers on the estimated financial gains from investment. This would allow the development of an improved understanding of the value that is added, and contribute to theory development with respect to the application of macrologistics concepts in infrastructure investment decision-making.

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## 4.3 Submitted article: "Intermodal solutions for the South African fast-moving consumer goods sector"

The article included in this section was submitted to the World Review of Intermodal Transportation Research in October 2020 and we are awaiting reviews[14]. The journal aims to provide an international forum for the critical evaluation and dissemination of research and development in all areas related to intermodal transportation theory and practice, and is of value to academics, practitioners and policy makers in this field. The South African FMCG sector case study is deemed to be of interest to the target audience as it highlights the sizable opportunity for intermodal services – a value chain technology – in the sector and discusses the critical success factors for implementing such a solution.

[14] This article was co-authored by Simpson, Z.P., De Bod, A., Havenga, J.H., Meyer, I. and Van Dyk, E. The formal declaration of author contributions, as required for publications included in dissertations by Stellenbosch University, is provided in Appendix A.

# INTERMODAL SOLUTIONS FOR THE SOUTH AFRICAN FAST-MOVING CONSUMER GOODS SECTOR


## ABSTRACT

Macro-level logistics cost and flow modelling have highlighted intermodal solutions as a means of optimising key South African (SA) freight corridors. This paper explores the critical success factors for translating the macro opportunity to a sustainable intermodal solution for the fast-moving consumer goods (FMCG) sector. The study identifies a significant growth opportunity for FMCG freight on rail, characterised by stable, naturally unitised volumes of low price elasticity. Intermodal solutions have the potential to facilitate a significant shift of freight from road to rail, thus reducing environmental impact. However, adoption of an intermodal solution requires a more flexible, focused, and responsive engagement from the rail service provider. The study succeeds in translating the quantified macro-level argument for intermodal solutions to the organisational implications and next tactical steps for the FMCG industry, to position towards sustainable implementation of intermodal solutions.


*Keywords: intermodal solutions, rail freight, road freight, logistics cost modelling, freight flow modelling, South African FMCG sector*

## 1 INTRODUCTION

The South African logistics landscape is characterised by structural inefficiencies, which impacts the optimal movement of freight and, ultimately, increases the cost of logistics. Given the role of logistics as enabler of economic activity and growth, this is unaffordable in any economy, but more so in developing environments where resources are limited.

A key consideration in the structural inefficiency in the South African logistics sector is the relatively large proportion of rail-friendly freight that is carried by road, due to constraints in the national rail system. Resolving this limitation is seen as a critical enabler of logistics cost reduction, and intermodal solutions have been put forward as a means of doing so. However, engagement with such solutions would require organisations to be in a position to adopt this new way of work.

This article explores the critical success factors that are required for the implementation of intermodal solutions in the South African context. It integrates the results of freight flow modelling, which illustrates the opportunity, with the results of a review of popular and academic literature, to identify the critical success factors that are required to make such solutions work from the perspective of different role players.

The study focuses on the fast-moving consumer goods (FMCG) sector, which represents a large proportion of the demand for South African logistics services. The inherent nature of the FMCG sector requires its logistics service providers to provide a cost-efficient service. At the same time, globalisation and new trends in technology and management practice are influencing logistics service provision. The case for intermodal and rail transport of FMCG goods is clear, given the sector's focus on cost reduction. However, for intermodal solutions to be successful, the FMCG sector and its supply chain complexities should be understood in such a way that appropriate and attractive service offerings can be developed in an environment where flexibility and agility is key, and where road transport currently dominates. Innovative approaches are required to ensure appropriate service delivery.

This article first summarises the research question and method followed (Section 2), after which it outlines the South African FMCG landscape, as deduced from popular and academic literature (Section 3). Section

4 describes the freight flow analysis that points to the intermodal opportunity, while Section 5 defines the nature of the intermodal opportunity. Section 6 summarises the critical success factors that are required to make such an opportunity work, from multiple perspectives, and Section 7 concludes.

## 2 METHOD

### 2.1 Objective

This study provides insights into the critical success factors that will determine the implementation and adoption of intermodal opportunities in the FMCG sector, by exploring and integrating information on a number of topics (see Figure 1). To this end, a scoping review of literature was undertaken, and results were integrated with freight flow information generated by freight demand and flow models (University of Stellenbosch, 2010).

The study aimed to answer the following questions:

- What is the current status of the FMCG logistics landscape?
- What is the nature and size of the opportunity for intermodal solutions in the FMCG sector?
- What are the factors that need to be in place to ensure that intermodal solutions are successful?

### 2.2. Scope and definition

The study considers all goods in the FMCG sector. For the purposes of this study, FMCG is defined as:

- Goods that are sold quickly and at relatively low cost;
- Goods that have a short shelf life, either as a result of high consumer demand or because it deteriorates rapidly; and
- Goods where the cash-to-cash cycle is fast.

Goods include non-durable goods, for example, fresh and perishable foods, non-perishable foods, personal care products, cleaning products, beverages, tobacco products, and paper and paper products, but excludes semi-durable and durable goods such as clothing, small appliances, sound equipment, cars and parts, bicycles, and others.

### 2.3. Flow model

The study is informed by the results of a South African freight flow model, which aids in illustrating the demands that different sectors of the economy place on the various freight corridors in the country. It uses the supply and demand values of an econometric model to model the movement of freight between supply areas (origins) and demand areas (destinations) throughout the country, for all commodities for all modes. The current model utilises 370 origins and destinations (magisterial districts, ports, etc.) and 83 commodities.

The input data for the flow model is created by subtracting the volumes of known freight flows per geographical district (rail, pipeline, conveyor and coastal shipping) from the total supply and demand volumes; the balance of supply and demand is then modelled as road flows using a gravity modelling approach.

Gravity modelling is based on the premise that freight flows between geographical districts are determined by supply and demand volumes for each commodity, and a measure of transport resistance. Transport resistance is determined by well-researched distance decay factors for each commodity. Distance decay varies from one commodity to another based on its nature and utility. Low value, bulk commodities generating a transport demand disproportionate to their value tend to have a sharp rate of decay (that is, they trend to not be transported long distances), while for higher-value commodities the impact of distance is smaller suggesting low decay parameters (mostly used for manufactured and end-use agriculture commodities, that is, heterogeneous agglomerations as their use is more dispersed over a number of geographical districts).

### 2.4. Literature overview

An overview of the literature informed some of the questions outlined above. Four bodies of knowledge were considered, namely: (1) FMCG sector; (2) FMCG trends; (3) current practice in FMCG logistics; and (4) leading international practice. Both academic and popular sources of information were interrogated. Limited academic sources were consulted. However, the studies that were used address issues in the FMCG sector in depth, and provide a sound basis from which to draw conclusions (see the Reference section for detail). Popular literature was used to provide insight into trends and initiatives in this fast-changing sector.

## 3. THE SOUTH AFRICAN FMCG LANDSCAPE

The FMCG sector comprises manufacturers, distributors, retailers, and logistics service providers, and the goods and services that are exchanged between them. This section describes the sector's size and role players, logistics services providers, and supply chain structure (Sections 3.1 to 3.3). Finally, it summarises the current management practice and future trends that are expected to influence the sector, along with the implications for rail service providers (Sections 3.4 and 3.5).

### 3.1. Sector size and key players

The South African food market was estimated to be worth R474 bn in 2016, of which the formal sector accounted for 68%. The turnover of the informal retail (spaza) sector was estimated to vary from R80 bn to R200 bn (Dicey, 2016). The 2018 value of the South African food and grocery market was estimated at R870 bn by a large South African retailer, of which the informal sector (the size of which is difficult to estimate) accounted for approximately 40% (Pick „n Pay, 2018).

#### 3.1.1. Major manufacturers and retailers

The 2018 turnovers of the major manufacturers are summarised in Table 1, as an indication of the size of the market [1].

*Table 1 Largest FMCG manufacturers in South Africa*

| Manufacturer | Turnover (2018) |
|---|---|
| Tiger Brands | R 28.5 bn |
| Pioneer Foods | R 20.2 bn |
| AVI | R 13.4 bn |
| Premier | R 9 bn |
| Rhodes Food Group | R 5.1 bn |
| Unilever | R 5 bn[1] |
| SABMiller (now AB InBev) | USD 10.3 bn[2] |

Note:

1. The Unilever turnover is an estimate for the local operation, based on the group's global revenue.
2. The SAB turnover reflects the 2018 value for the EMEA operation.

Sources: AVI, 2018, Pioneer Foods, 2018; Premier, 2018; The Rhodes Food Group, 2018, ABInBEv, 2018; Tiger Brands, 2018; Unilever, 2018. [1]

The five major retailer groups account for approximately 55% of the formal sector. Their respective turnovers and number of stores are shown in Table 2 [2]. Although these numbers include non-FMCG products and outlets (e.g., clothing, furniture and appliances, DIY, and pharmaceuticals), it provides an indication of the size of the sector.

***Table 2 Largest retailers in formal food market in South Africa***

| Retailer | Turnover (2018) | Number of stores (2018) |
|---|---|---|
| Shoprite Holdings | R145.3 bn | 2843 |
| Massmart | R90.9 bn | 436 |
| Pick ‟n Pay Group | R81.7 bn | 1685 |
| Woolworths Holdings | R75.2 bn | 712 |
| Spar Group | R68.8 bn | 2236 |

Sources: Massmart, 2018; Pick ‟n Pay, 2018; Shoprite Holdings Ltd, 2018; The Spar Group Ltd, 2018; Woolworths Holdings Ltd, 2018 [2]

### 3.1.2. Major Carriers

A number of large carriers serve most of the South African FMCG sector [3]. Imperial Logistics operates South Africa‟s largest cold storage warehouse with over 37 000 pallet locations, while Vector Logistics provides bulk cold storage as well as multi-temperature warehousing, and Unitrans provides warehousing. Long-distance transport to retail distribution centres is provided by Imperial Logistics, LiebenLogistics, Themba Group, Unitrans, Value Logistics, and Vector Logistics.

Barloworld Logistics delivers multi-temperature loads to 6000 delivery points per month. This includes retailers as well as the forecourt and convenience sector. Supergroup is the largest distributor in the convenience market segment, distributing to more than 18 000 forecourts and convenience stores, and can accommodate ambient, chilled, and frozen products in a single delivery. Value Logistics manages break bulk and full truck loads to large retailers‟ distribution centres (DCs) as well as deliveries to supermarkets, independent retailers, cash & carry, and retail back doors. It includes a rental fleet of refrigerated trucks for FMCG products, and offers a specialised distribution service to approximately 8000 informal stores such as spaza shops and convenience stores. The retailer Shoprite has its own vehicle fleet for secondary distribution. Their truck fleet travels approximately 70 million km annually to deliver over 7 billion products.

## 3.2. Structure of supply chains

Figure 2 summarises South Africa's FMCG value chains. There are two main routes for products from suppliers to consumers, namely, through the formal or informal sectors. In the formal sector, products flow from the supplier (manufacturer) either via a DC or directly to a supermarket where a consumer buys the product. However, the global trend is shifting away from direct store deliveries to centralised DCs – most supermarket chains in South Africa now have multiple DCs. The consumer could also buy the product online, in which case it will probably be delivered directly from the DC to the consumer.

In the informal sector, low-income consumers buy from spaza shops and other independent retailers. The latter often belong to buying groups that buy in bulk from suppliers, but they lack access to DCs and therefore forfeit the supplier discounts for sales to DCs (Das Nair et al., 2016). Spaza shops and consumers may also buy from „hybrid‟ wholesalers such as Makro (Das Nair et al., 2016). In 2016, Pick ‟n Pay entered into their first partnership with a spaza shop, which provides the spaza owner with access to the Pick ‟n Pay procurement and distribution system. There are currently 14 Pick ‟n Pay spaza partner shops (Pick ‟n Pay, 2018).

### 3.2.1. Primary versus secondary distribution

As explained above, most supermarket chains have DCs. FMCG products are typically first transported in full truck loads from a single production facility to a single DC, referred to as primary transport. At the DC, products from different manufacturers are combined into loads for stores. A single truck can deliver loads to multiple stores. This is referred to as secondary distribution.

Some manufacturers have numerous routes to market, as is evident in Figure 3. This figure shows, as example, the distribution network of the snack producer Simba. The beverage producers Coca-Cola and SAB similarly often deliver directly to stores rather than retailer DCs.

Suppliers provide value-added services with direct store deliveries (DSD) to improve sales and margins for the retailer. Table 3 compares the benefits of DSD to centralised distribution networks (CDN). Some suppliers generate and increase sales revenue and throughput volume by maintaining tight control over their DSD networks (authors‟ analysis).

***Table 3 Benefits of different distribution models***

| | Direct-to-store delivery (DSD) | Centralised Distribution Network (CDN) |
|---|---|---|
| •<br>•<br>• | Out of stocks 2 – 4% less than when delivered via DC<br>Reduction in shelf-tag and scan errors<br>Merchandising time spent handling item | • Reduction in backroom inventory for stores<br>• Shift 95% of cost of goods from DSD channel to company‟s own CDN |
| •<br>•<br>•<br>• | data is reduced by 5 – 10%<br>0.5 – 1.0% reduction in inventory of retail distributor<br>1+% reduction in retail warehouse labour hours<br>2 week reduction in speed to market for new items<br>5 – 10% reduction in finance time and audit fees spent reconciling invoices | • Reduction in logistics and retail labour cost with improved customer service levels<br>• Reduction in number of deliveries received at stores<br>• Improvement in inventory turns resulting in reduction of working capital tied up in inventory<br>• Risk pooling to minimise safety stock<br>• Improved store service levels due to better fill rates<br>• Shorter order lead time |

In spite of the benefits listed above, the use of DSD is highly inefficient for the majority of FMCG products. There are some exceptions, for example, products with very short shelf life or that can easily be damaged during handling, highly specialised products that require supplier knowledge, and low volume products that are better delivered by parcel service. Nevertheless, DSD is a very expensive route to market.

### 3.2.2. FMCG supply chain characteristics

FMCG supply chains need to be very flexible and responsive to ensure on-shelf availability of products. They need to accommodate:

- Highly perishable products that could easily be contaminated, for example, fruit and vegetables, dairy, and meat;
- Fragile products that need to be handled with care, for example, biscuits and chips;
- Large numbers of products (SKUs) and suppliers;
- Seasonal products and/or demand, for example, wine and liquor before Christmas;
- High levels of promotional activity that affects product volumes (large volumes ahead of the promotion followed by small volumes for a month or more after the promotion); and
- Potentially long supply lead times for imported products.

The effects of seasonal demand are illustrated in Figure 4, which shows an example of the number of primary loads per week for a beverage manufacturing company. There are very high peaks before Christmas and New Year, followed by very low demand during January.

## 3.3. Local practice and future trends

To understand the maturity of the environment within which new solutions need to be developed, the current local practices with respect to FMCG logistics were explored, and future trends that would influence the sector were identified from the literature. These are summarised in Table 4. For each practice or trend, the implications for the rail service provider have been identified.

*Table 4 Summary: Implications for rail service providers*

| Aspect | Impact on retailers | Implications for rail service provider |
|---|---|---|
| **Economic outlook** | Pressure to reduce cost and improve efficiencies | Provide an appropriately priced lowcost service that can connect with complex FMCG supply chains. |
| **Consumer trends** | Customers are expecting better service at lower costs | Design low-cost solutions that provide a predictable service for primary distribution, which can engage with flexible and responsive secondary distribution networks. |
| **Technology** | Technology is a key enabler of advanced supply chain performance | Rail service providers should be able to integrate technology into their transport solution to enhance visibility and predictability, and should be able to connect with the technology solutions in the secondary distribution system. |

| | | |
|---|---|---|
| **Collaboration** | Collaboration is essential for supply chains to remain competitive. It is facilitated through technology solutions, and facilitates improved supply chain performance. | As above.<br>The rail service provider should have a culture of collaboration and solution development across organisational boundaries. |
| **New entrants** | Some manufacturers and retailers are developing in-house logistics solutions to reduce cost and improve service delivery. | The rail service provider should package its inherent costeffectiveness in a primary transport solution that is seamlessly integrated with the rest of the logistics solution. |
| **Sustainability** | There is increasing pressure on supply chains to reduce their environmental footprint. | Rail is a preferred green transportation option for longdistance FMCG transport, provided that flexibility and service delivery can be maintained |

Local practice and the implications for rail service providers are summarised in Table 5:

***Table 5 Summary: Implications for rail service providers***

| Local practice | Status | Implications for rail service provider |
|---|---|---|
| **Management practice** | | |
| *Collaboration* | Facilitated by lean and agile initiatives, and essential to success in an increasingly competitive FMCG environment. | The successful performance of the rail service provider will depend on the ability to integrate its primary distribution network with secondary transport solutions. |
| *Risk management* | Risks related to labour unrest, volatile demand, and unreliable suppliers dominate.<br>Risk mitigation includes flexible transportation strategies. | The rail service provider needs to integrate successfully with the secondary transport network in a manner that facilitates flexibility and agility of the overall transportation solution.<br>Predictable service is key. |

| | | |
|---|---|---|
| *Supplier selection* | *Top categories of selection criteria:* cost and price structure, service delivery, service provider relationship. *Key individual criteria:* collaboration, information management and compliance, service quality. | Rail provides an inherently costeffective alternative; the focus should be on service quality, relationship development and trust, and integration with client operations. |
| *Green supply chains* | Increasing focus and pressure on retailers to develop green supply chains. | The rail service provider should use its inherent advantage as a preferred green transportation option for long distance FMCG transport to offer solutions that also enable flexibility and service delivery. |
| **Technology adoption and use** | Technology is well adopted in support of supply chain integration and collaboration. | Integration with FMCG client systems is essential. |

## 4. Identification of rail- and intermodal-friendly freight

The main logistics infrastructure elements are indicated in Figure 5.

### 4.1. Freight flows

Figure 6 shows the major overland freight flows. It is clear from the graphs that the importexport containers (IMEX TEU) and domestic intermodal freight are transported mostly by road.

High density freight that flows over longer distances are highly suitable for rail transport. Rail-friendly freight is, therefore, defined as freight flows between dense origin–destination pairs of 100 000 tons per annum (a minimum of one train per week) over distances longer than 500 km. The portion of this freight that is suitable for intermodal transport was defined as „palletisable‟ goods, that is, freight that can be easily packed on pallets and stacked in containers (Havenga et al., 2012). Table 6 shows the total volumes (in ton-km) of each of the top ten palletisable commodity groups transported as well as the volumes transported on corridors. The total volumes of palletisable freight on the main corridors are shown in Table 7. FMCG products (processed foods and beverages) are the top two palletisable commodities in terms of volumes, while Cape Town-Gauteng (Capecor) and KwaZulu Natal-Gauteng corridor (Natcor) account for the largest flows.

*Table 6 Top ten palletisable commodity groups*

| Commodity group | Corridor ton-km (in billions) | Total ton-km (in billions) |
|---|---|---|
| Processed Foods | 17 | 22 |
| Fuel & Petroleum Products | 6 | 9 |
| Beverages | 5 | 6 |
| Chemicals | 5 | 6 |
| Cement | 2 | 4 |
| Wood timber & products | 2 | 3 |
| Iron & Steel | 2 | 3 |
| Paper | 2 | 2 |
| Fertilizer | 1 | 2 |
| Other petroleum products | 1 | 1 |

Ton-km: a unit of freight carriage equal to the transportation of one metric ton of freight one kilometer.

*Table 7 Palletisable freight on major corridors*

| Corridor | Palletisable freight ton-km (in billions) |
|---|---|
| Gauteng – Cape Town | 7 |
| Gauteng – Durban | 5 |
| Gauteng – Richards Bay | 0.4 |
| Cailtzdorp – Port Elizabeth | 1 |
| Aliwal North – East London | 0.6 |
| Steelpoort –Mozambique | 0.2 |
| Gauteng – Musina | 0.6 |

## 4.2. Rail versus road transport

Rail transport is much cheaper and more environmentally friendly than road transport. In Table 8, the percentage by which rail is cheaper than road is shown for different countries.

*Table 8 Rail vs. road cost*

| Country | % by which rail is cheaper than road |
|---|---|
| USA[1] | 175% |
| International[2] | 122% |
| Germany[3] | 100% |
| South Africa: All freight[4] | 245% |

Sources:
1. Kehoe (2003).
2. Brakman and Garretsen (2005).
3. Federal German Water and Shipping Administration (2007).
4. University of Stellenbosch (2010).

Global rail networks carry 7% of freight transport and 8% of the motorised passenger transport, but consume only 2% of the energy used in the transport sector (IEA, 2019).

Rail is significantly more energy efficient than road or air transport: for example, rolling friction losses of steel-to-steel contacts are 85–95% lower than those of truck tyres. Further, trains can transport very high volumes of freight and stop infrequently owing to traffic segregation. In 2016, rail transport accounted for 0.3% of direct $CO_2$ emissions from fossil fuel combustion (IEA, 2019).

Freight rail accounted for approximately 4% of all well-to-wheel greenhouse gas emissions in the freight transport sector, which is much lower than its 7% share of freight transport activity. As rail is widely electrified, it has the possibility to further reduce its carbon emissions by being able to utilise energy from coal-fired power plants that switch to renewable energy. Rail saves more oil than it consumes and reduces more emissions than it emits. The global oil consumption would increase by 15% and greenhouse gas emissions by 1.2 gigatonnes $CO_2$-equivalent if all passengers and freight currently transported by rail were to be moved to road (IEA, 2019).

Further advantages of rail, as well as the benefits of road transport to the FMCG sector, are listed in Table 9.

*Table 9 Advantages of rail and road for FMCG*

| Advantages of rail | Advantages of road for FMCG |
|---|---|
| • Cheaper<br>• Security<br>• Sustainability<br>• Natural consolidator of freight<br>• Increases longevity of road network<br>• Enables natural clustering of industry<br>• Improves global connectivity<br>• Improves competitiveness of freight system | • Road is door to door<br>• Flexible and adaptable<br>• Suitable for smaller parcel sizes<br>• Quicker fulfilment<br>• Shorter lead time<br>• Lower cycle stock<br>• Reliable<br>• Reduced double handling (stuff/destuff) |

# 5. THE INTERMODAL OPPORTUNITY

## 5.1. Key considerations

Retailers are driven by the need to keep their shelves full at the lowest cost, which has implications for the entire supply chain. For rail service providers to participate in this chain, the concerns of retailers need to be addressed. Key questions are summarised in Table 10, along with answers that have been gathered from a review of the literature:

***Table 10 Positioning for service provision***

| Question | Summary Response |
|---|---|
| **Are the needs that *Matter Most* to customers understood?** | • Low cost, reliable logistics service provision that enables reliable, consistent availability of products of the required quality and volume across all stores. |
| **What needs must be satisfied to make customers switch to Rail / Rail-Based Logistics Solutions?** | • Reliable service<br>• Low cost service<br>• Flexibility<br>• Agile service<br>• Service quality<br>• Low environmental impact |
| **What opportunities can be exploited by correctly assessing and defining needs?** | • Low-cost long-haul FMCG transport Environmentally<br>• friendly transport |
| **How may Industry 4.0 alter customer needs?** | • Increased demand for visibility, security, and communication |
| **What should be focused on in satisfying customer needs, and how should it be done?** | • Integration with existing systems and processes<br>• Collaboration with primary logistics service providers<br>• Development of relationships and trust with clients and other logistics service providers<br>• Use of advanced technology to satisfy customer needs |

## 5.2. The nature and size of the market opportunity

The market for FMCG freight is comprised of two segments, namely an Import / Export opportunity, and a domestic intermodal opportunity. Within this segmentation, South Africa's current focus and capability is to service Import / Export FMCG, while the future growth opportunity can be found in a domestic intermodal solution. The FMCG opportunity is characterised by stable volumes of freight, which is naturally unitised or palletised, can easily be transported in a container, has low price elasticity, and is therefore ideally suited to intermodal transport. The size of the opportunity is summarised in Table 11, where the international and domestic markets for FMCG freight are indicated in terms of thousands of TEUs, for the total network, as well as for the two main corridors.

*Table 11 FMCG market size*

| CORRIDOR | Market Size (Thousand TEUS) | |
|---|---|---|
| | International | Domestic Intermodal |
| **Total network** | 2 290 | 3 937 |
| **Gauteng – Durban** | 1 500 | 732 |
| **Gauteng – Cape Town** | 450 | 718 |

### 5.3. A domestic intermodal solution for FMCG freight

Figure 7 shows the similarities and differences between international intermodal and domestic intermodal operations. Imported goods mostly enter the country in containers via sea ports. The containers are transported from the sea port to an inland container depot or distribution centre, where they are destuffed. The goods are then distributed to the retailers or other customers. Export goods follow the reverse flow. A sea port is a natural hub from where a large number of containers need to be transported. In contrast, domestic goods first need to be stuffed into containers before it can become intermodal freight. Instead of transporting individual containers over long distances by road to DCs, they could be taken to a consolidation centre (intermodal facility) to be loaded onto a train for transport to a hub (intermodal facility) near the customer DCs.

A domestic intermodal freight solution requires the ability to deliver a ***predictable service*** for palletised freight between hubs (as depicted in Figure 8). In this configuration, the hubs provide the opportunity and buffers to accommodate retailers' need for flexibility, while the rail link is integral to the delivery of a low-cost solution of relatively low environmental impact.

For rail to deliver a viable service, regular trains at full capacity needs to be moved. This can be achieved by:

- ***Filling trains*** with multiple loads from various customers, and delivering an ondemand service, OR
- ***Selling trains*** in the form of a regular service between hubs, where the nature of the ownership of the freight (customer identity) is not a key consideration.

In the latter case, the rail service provider can optimise operations and reduce cost, while the logistics hub facilitates integration of freight from different customers. The complexity for the rail service provider is decreased, while predictability for customers is increased. This represents a mode of operation that is native to rail.

### 5.4. Implementation

While the ***selling trains*** solution outlined in Section 5.3 is less complex and more native to the rail service provider, the FMCG environment still requires a more flexible, more focused, and more responsive engagement from logistics service providers. This places specific demands on the organisational capability of the service provider. In addition, the service provider needs to develop a viable business from the opportunity in FMCG. Specifically, the organisational capabilities as specified in Table 12 are required:

*Table 12 Organisational capabilities required for FMCG service provision*

| | Organisational capability | Description |
|---|---|---|
| STRATEGIC / TACTICAL | Stakeholder engagement | • Development of relationships and trust with clients and other logistics service providers |
| | Culture of collaboration | • Collaboration with clients and logistics service providers to optimise clients' supply chain performance |
| | Business development | • Appropriate value offering<br>• Market intelligence |
| | Skills development | • Appropriate technical skills (information systems, process integration etc.) |
| OPERA - TIONAL | Customer focus | • Urgency to satisfy customer needs |
| | Service excellence | • Reliable, predictable, flexible service |
| | Operational excellence | • Low cost service |

The FMCG market opportunity requires the rail provider to exhibit market-focused, flexible behaviour, which is different to the approach required by most of the commodities that are naturally carried by rail. The service provider therefore needs to give adequate consideration of its ability to exhibit such behaviour.

It requires commitment from management, market-focused sales and marketing engagements, and adherence to the achievement of operational efficiency and service excellence.

This approach firstly requires high-level management commitment to service the sector, and to structure the incentives that are required to drive appropriate behaviour. Further, the rail service provider needs to structure itself into a savvy market player that is able to develop deals in an environment where multiple role players deliver on the logistics needs. Finally, operations should be structured in a manner that facilitates the required cost and environmental benefits, and that allows integration with the processes and systems that are required to deliver a flexible logistics offering.

## 6. CRITICAL SUCCESS FACTORS

The successful implementation of domestic intermodal solutions has different critical success factors (CSFs) for different role players. These are summarised below, for each perspective.

### 6.1. CSFs for intermodal solutions

Van Binsbergen et al. (2014) define a focus on complementary transport, rather than intermodal transport per se, as essential to the development of a sustainable transport system. They identified the following success factors in intermodal transport initiatives in Europe, highlighting technology as well as process factors (Van Binsbergen et al., 2014: 18):

**System characteristics**

- *Relative advantage:* the degree to which the intermodal transport innovation is perceived to perform better than the existing intermodal transport option or competing modes (e.g. road-only transport). The better performance may for instance relate to transport costs, transit time, reliability and/or flexibility.
- *Compatibility*: transport and logistics chains. Compatibility can be an issue from technological and/or organizational perspective.
- *Complexity:* the degree to which the intermodal transport innovation is perceived as relatively easy to develop (e.g. using proven-technology), understand and use.
- *Testability:* the degree to which an innovation can be experienced and tested.

**Innovation system and process:**

- *Composition and diversity of actors involved (stakeholders):* number and type of actors and their interests, balance of power of actors, distribution of costs and revenues between actors, the role of investment actors (capital/subsidies), the role of lobby groups and/or public opinion.
- *Characteristics of competitors:* degree of market competition, possibility for niche-market development
- *The role of government:* government can be involved in different ways and levels

(facilitating, initiating, developing / financial, legal, co-ordination)

These factors, or similar, could serve as guidelines in developing and assessing the design of intermodal solutions.

### 6.2. CSFs for Logistics Service Providers

In a survey of supermarket suppliers, the most important success factors from the suppliers‟ perspective were the ability to consistently supply products at the lowest cost, required quality, and volume across all stores. For franchise stores, the consistent supply of products across stores is less crucial, which enables smaller suppliers to only serve stores in a particular region. Although the location of suppliers affects the logistics costs, suppliers did not consider it to be an important factor. Suppliers of perishable products and processed foods prefer to be close to the market, whereas suppliers of low-value, high volume products such as maize meal are typically located close to source (Das Nair et al., 2016).

A 2016 global survey of transport and logistics (T&L) CEOs identified changing market environments and stakeholder expectations. Although 79% of T&L CEOs felt that their customers are mainly interested in cost, convenience, and function, the other 21% believed that customers want to build relationships with companies that address wider needs. Some customers already choose service providers based on their social and environmental impact, and more are expected to include these criteria in their purchase decisions in future. Technology was seen as a driver of change as well as a tool to meet customer needs; 73% of T&L CEOs regarded technology as one of the top three global trends that would influence customer expectations over the next five years. Real-time tracking of shipments was already the norm in the logistics industry (PwC, 2016).

In the same year, PwC‟s future-in-sight report for the logistics industry identified four areas of disruption, namely customer expectations, technology, new entrants, and collaboration (PwC, 2016). Each of these areas is briefly elaborated on.

**Customer expectations**

Retailers and manufacturers are expecting better service, such as improved traceability and predictability, at a lower cost from LSPs.

**Technology**

A number of important technologies could affect LSPs. For example, blockchain could be used to follow the location of cargo in close-to-real time as goods-in-transit security is a major concern (LeClair, 2018; Ovchinnikov, 2018). „Digital fitness‟ is becoming a prerequisite for LSPs, but the biggest challenge for developing digital operations capabilities in LSPs is a lack of digital culture and training. Given the range of technologies available, it is essential to define a digital strategy and integrate it into the business strategy.

**New entrants**

Some manufacturers and retailers start up their own logistics operations in competition with LSPs. New entrants often use technology and new business models to offer lucrative services without investing in expensive assets.

**Collaboration**

Collaboration amongst LSPs exists almost exclusively for last-mile deliveries. The concept of a „Physical Internet‟ has been proposed to standardise shipment sizes, protocols and system interfaces, as well as synchronise hubs and networks across transport modes in order to facilitate collaboration, which could result in cost savings due to increased efficiency.

Based on the above areas of disruption, four possible future scenarios have been identified for the logistics industry (PwC, 2016).

- *Sharing the PI(e):* Customers demand cheap, green, and fast supply chains, forcing LSPs to reduce their environmental impact and increase their efficiency by collaborating more and sharing networks. The „Physical Internet‟ leads to common standards for shipment sizes, communication and data exchange.
- *Start-up, shake-up:* New entrants take market share in the courier-express-parcel (CEP) space by offering e-marketplaces and blockchain technology for logistics services. These new entrants collaborate with 3PLs and complement their services, especially for last-mile delivery (e.g. by using crowd-delivery solutions).
- *Complex competition:* Big online retailers start their own logistics services to reduce their dependence on LSPs. They perform their own customer behaviour analysis to optimise their supply chains and switch to automated warehouses.
- *Scale matters:* Incumbents increase their geographical coverage through mergers. They acquire new technologies, or new entrants with promising technologies, and staff with critical skills to streamline their operations and dominate the market.

According to PwC (2016), „logistics companies will need to focus on “digital fitness”, cost efficiency, asset productivity, and innovation if they want to meet changing expectations‟.

### 6.3. CSFs for Rail service providers

Critical success factors for moving freight to rail from road (through intermodal solutions) include:

- High volumes of goods to be moved;
- Uniform freight (e.g., through containerisation);
- Transport over longer distances to benefit from lower cost;
- Predictable service;
- Block trains with minimal shunting; and  Bi-directional traffic.

The rail service provider should be able to deliver a predictable service at low cost to ensure viability, and to unlock the benefits of rail to the FMCG distribution network.

Further, the smart logistics hub should facilitate seamless integration of freight across modes. This implies that the rail service provider should have advanced capabilities in technology, systems, processes, and organisational culture and structure that enable integration with the hub.

Lastly, the solution should attract sufficient flows of the appropriate nature to ensure economic viability. A holistic view should be taken when designing intermodal solutions, with cognisance of factors that beyond the design of the system (including organisational and process factors).

## 7. CONCLUSION

The brief overview of the FMCG sector (Section 3) and the subsequent interpretation of railfriendly freight in this context (Sections 4 and 5) emphasize that rail in the South African context could be a preferred service provider for FMCG freight. The development of intermodal solutions is hence considered appropriate and necessary in this sector. The following reasons have been highlighted in the analysis:

- The FMCG sector's demand for freight is significant, with a large current and potential market;
- The majority of the South African FMCG freight travels by road;
- Rail offers advantages that match specific sector demands, especially in terms of cost, sustainability, and security;
- The use of rail has secondary advantages for the national transport network and the economy;
- The transport distances for most freight is either 650 km or 1 400 km, which is significant;
- This freight travels between three natural catchment areas; and
- Rail could therefore be the preferred long-haul provider for FMCG freight.

However, this shift from road to rail and the adoption of inter-modality requires a new way of work, for all role players involved. Amongst others, the rail provider should be able to connect with a complex supply chain, that is driven by a demand for flexibility and agility. Further, the rail service provider needs to be able to provide a domestic intermodal service, that is, transport stuffed containers between logistics hubs (DCs) between cities.

Critical success factors include the development of a sustainable transport system, that includes both processes and technology; the ability of logistics service providers to provide a service to retailers that fulfils their demands for continuous supply of goods while collaborating, traversing complex competition, new entrants, and new technology; and the ability of the rail service provider to consolidate freight in a manner that enables high volumes to be moved over longer distances at low cost, and to provide a reliable service. This would require that the South African rail service provider restructures the way in which it engages with potential FMCG customers, adopts the appropriate technology, systems, and processes, and develops the organisational culture and structure that enables integration with a smart logistics hub.

This study integrated results from a South African freight flow model and a review of (mostly) popular literature to motivate the case for intermodal solutions in the FMCG sector, and to outline the factors that are critical to its successful implementation. The work considered logistics service providers to the FMCG sector in general and the rail service provider specifically, as well as producers and retailers. It did not consider the broader policy environment within which the rail service provider operates, or the enabling environment for the FMCG sector. Further, the focus was on the larger role players. Future work could investigate the context within which intermodal solutions are proposed in more depth, and consider the impact on smaller players. Further, the literature review could be extended to include interviews with key stakeholders, so as to highlight expected barriers and enablers to implementation of intermodal solutions in the sector. Finally, from the perspective of sustainable systemic solutions for the logistics industry, the development of cross-sectoral intermodal solutions should be explored. Note that this study was conducted before the Covid-19 pandemic.

**CONFLICT OF INTEREST**

The authors declare no conflict of interest.

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**Notes**

**[1]Sources of manufacturers' information** http://www.tigerbrands.com/ http://www.pioneerfoods.co.za/ https://www.avi.co.za/contact-us/ https://www.premierfmcg.com/About-Us-Business-Footprint.aspx?s=0 http://www.rfg.com/our-business/ https://www.unilever.co.za/about/who-we-are/about-unilever-south-africa/ http://www.sab.co.za/

**[2]Sources of retailers' information** https://www.shopriteholdings.co.za/trade-partners/supply-chain-management.html https://www.massmart.co.za/our-business/overview/ http://www.picknpayinvestor.co.za/ https://investor-relations.spar.co.za/ https://www.woolworthsholdings.co.za/

**[3]Sources of logistics service providers' information** https://www.barloworld-logistics.com/ https://www.imperiallogistics.com/businesses.php https://tscc.co.za/divisions/tscc-fmcg/ https://liebenlogistics.co.za/about-us/ http://www.supergroup.co.za/supply-chain/africa https://www.unitrans.co.za/index.php/foods-_-fast-moving-consumer-goods/ https://value.co.za/retail-deliveries/ https://www.vectorlog.com/customers/

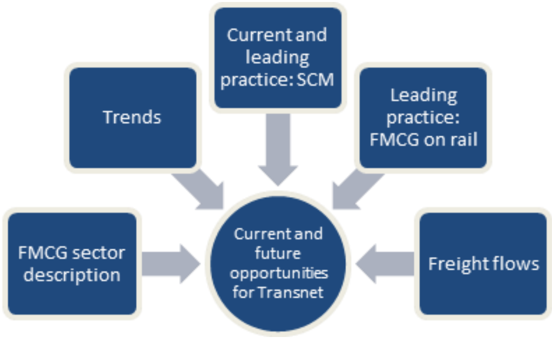



*Figure 1 Research overview*

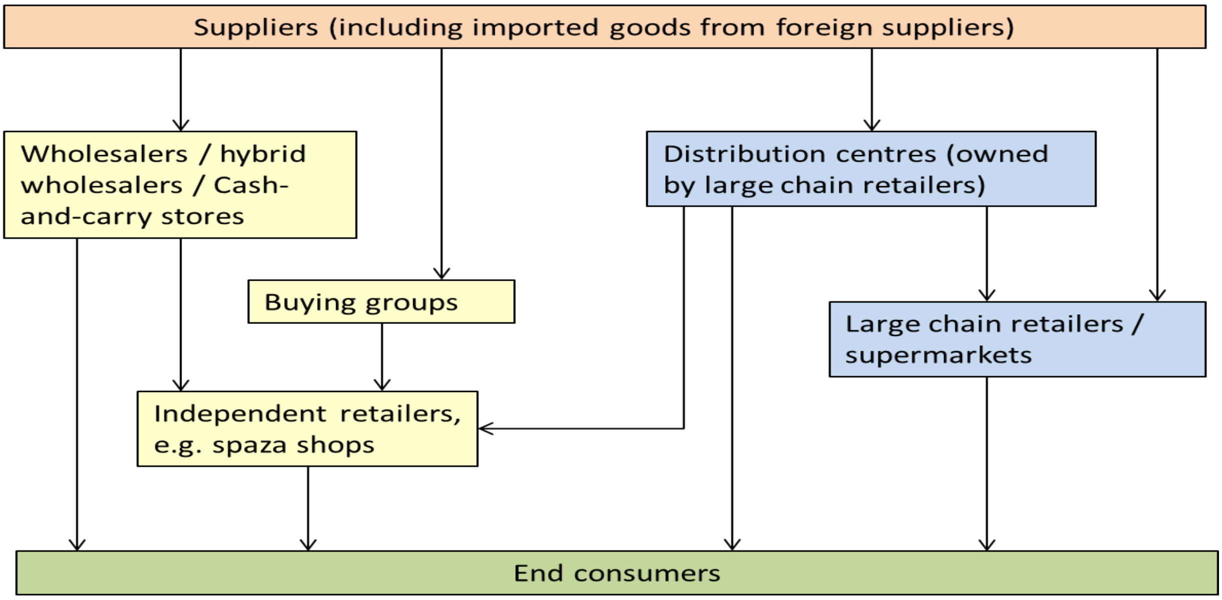



*Figure 2 Value chains for FMCGs in South Africa (Source: adapted from Das Nair et al., 2016)*

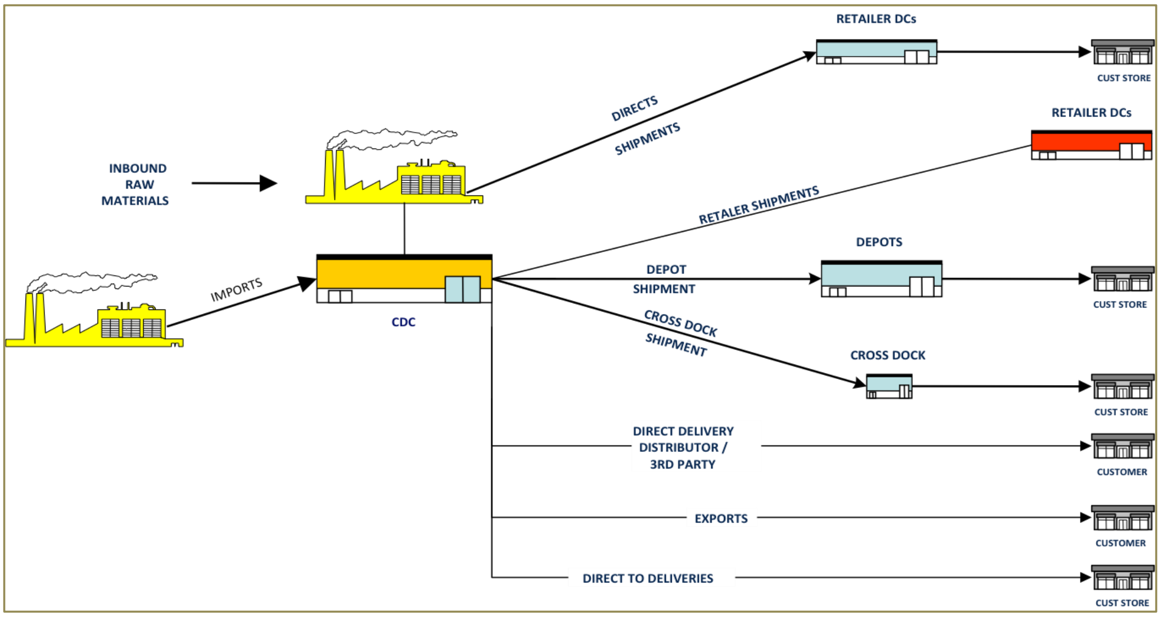



*Figure 3 Simba's distribution network* (source: authors)

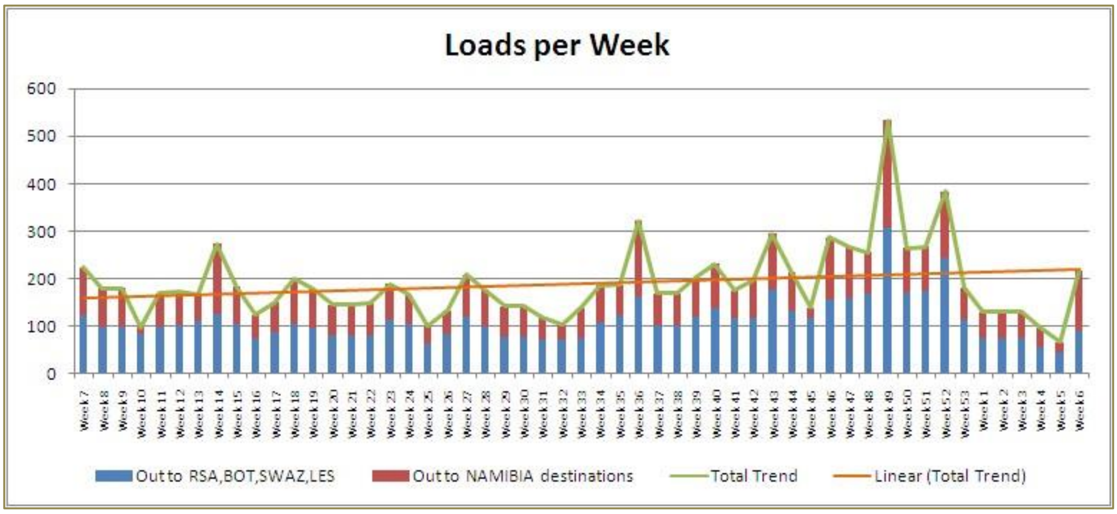



*Figure 4* *Primary loads per week for beverage manufacturer* (source: authors)

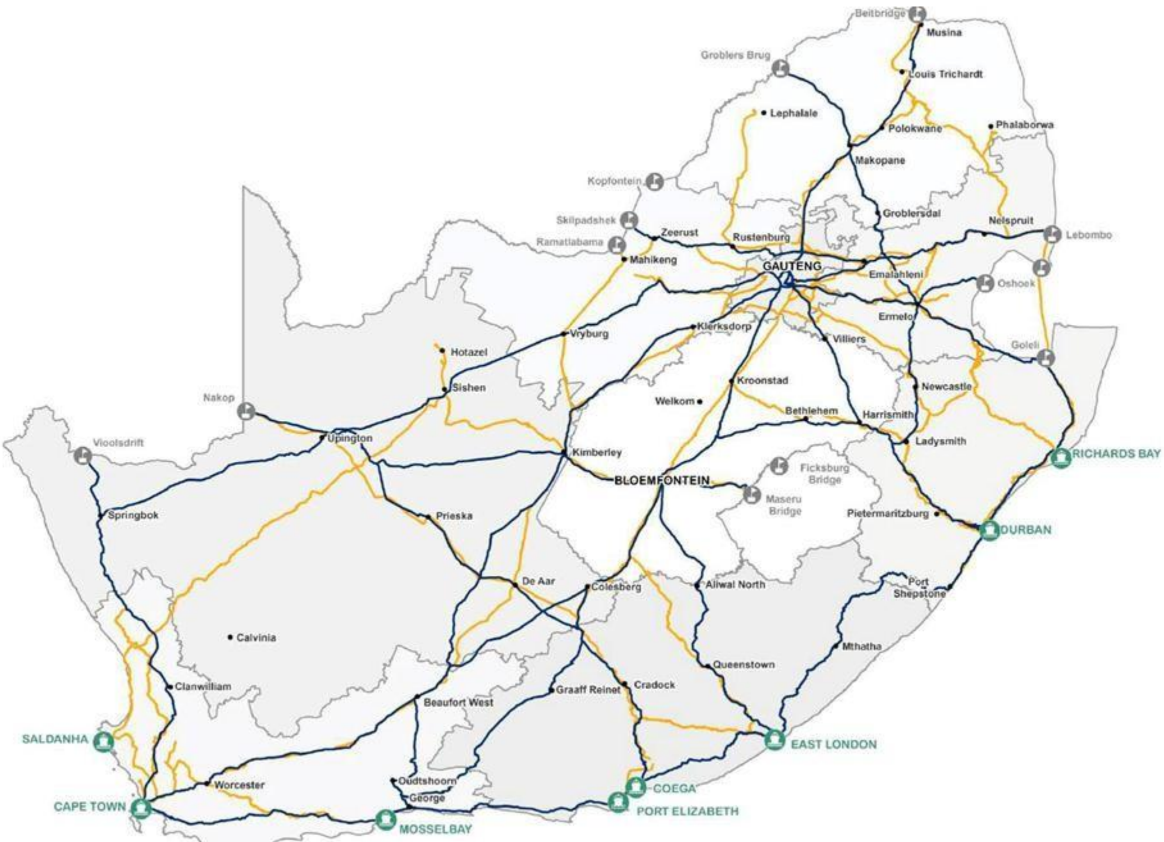



*Figure 5* *Key national logistics infrastructure elements* (source: authors)

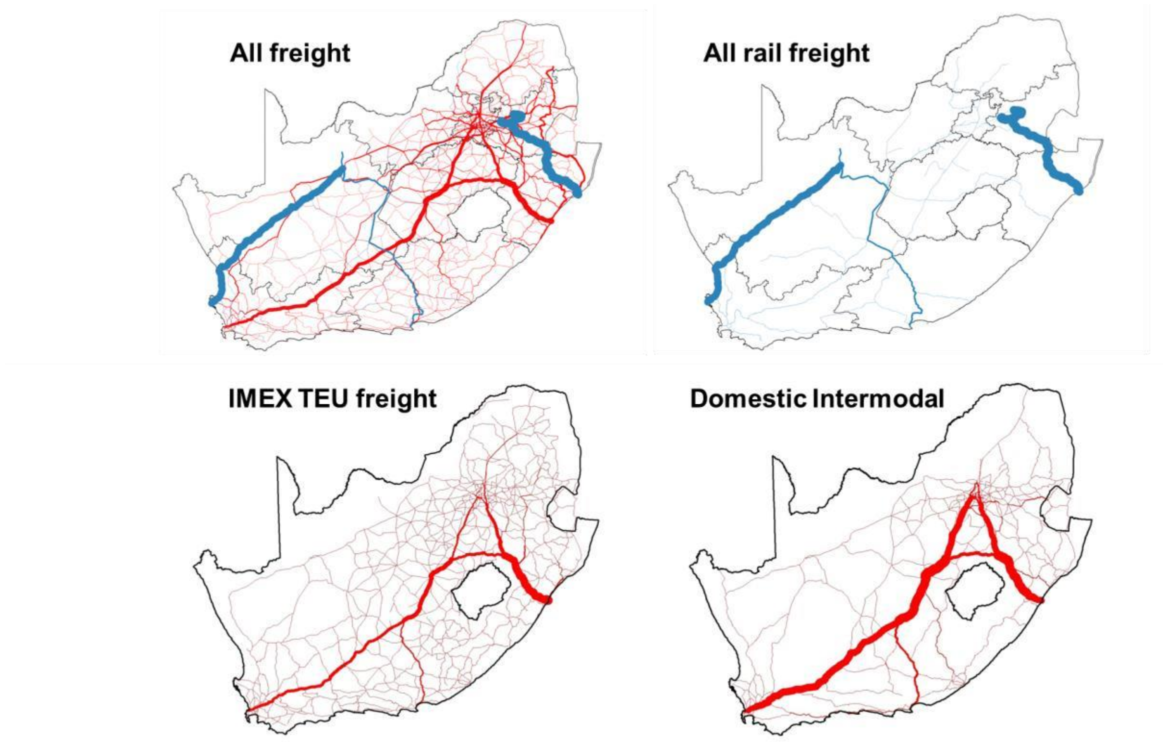



*Figure 6 Freight flows*

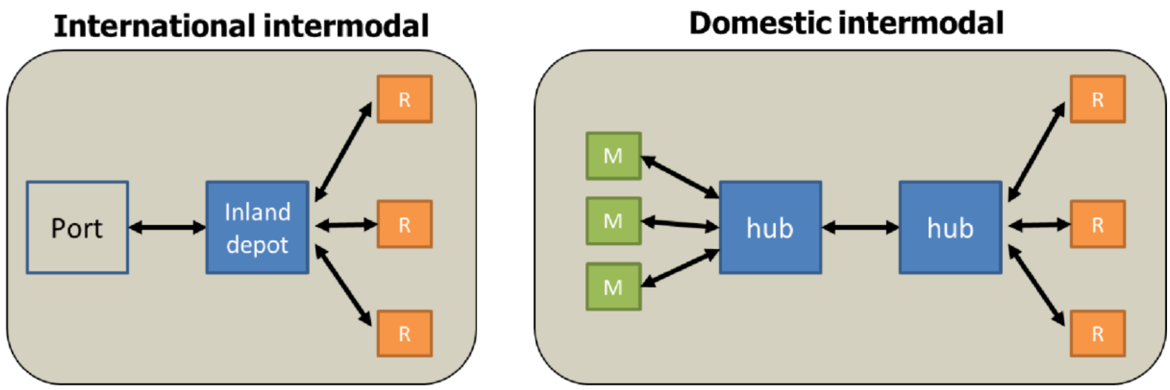
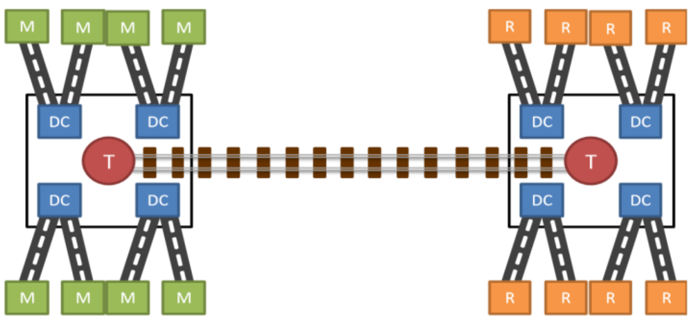



*Figure 7 International vs domestic intermodal operations*




M = Manufacturing
DC =Distribution Centre
R = Retailer
☐ =Natural Logistics Hub
T = Terminal

*Figure 8 Domestic intermodal freight service*

## 4.4 Summary: Re-imagining macrologistics value chain development

The publications included in this chapter succeeded in meeting the following research objectives:

RO3: Illustrating the utility of the outputs from the DNFDMs through application in:

RO3.2: Re-imagining macrologistics value chain development

In this chapter two case studies were presented where the objective was to illustrate the utility of the outputs from the DNFDMs to re-imagine macrologistics value chain development.

In the first case study, a structural and spatial reconfiguration of Mongolia's livestock value chain to support economic diversification and regional development was proposed, utilising the Mongolian DNFDM volumetric outputs in combination with a descriptive value chain analysis.

In the second case study, the density and cost reduction opportunities of domestic intermodal solutions for the FMCG industry was confirmed with outputs from the South African DNFDM. Subsequently, the critical success factors to facilitate the successful development of such solutions were discussed.

While the execution details differ significantly, in both case studies the freight-flow analysis indicated fragmented, yet ultimately high density, freight flows between major supply and demand areas resulting in high logistics costs and suboptimal value chain performance. Both case studies highlight the benefit of consolidating regional freight flows with similar logistics requirements at newly established logistics hubs or freight villages (locations determined by freight densities from the DNFDMs) to optimise long distance transport and reach target markets more effectively. In both cases, rail proves to be a more efficient long distance transport solution. The rail service provider should package its inherent cost-effectiveness in a predictable long-distance transport solution which can engage seamlessly with flexible and responsive road distribution networks. The logistics hub or freight village facilitates integration of freight from different customers and can provide support services where required.

The case studies support selectivity in infrastructure investment decision-making by combining strategic value chain analyses and disaggregated freight flow modelling. An assessment of the infrastructure required for value chain optimisation which takes all the related freight flows into consideration provides evidence-based support for infrastructure investments that could unlock the most value, and for policy development that enables a coordinated approach to infrastructure development.

# Chapter 5. Conclusion

This chapter concludes the dissertation by summarising the research presented (Section 5.1), highlighting the unique contribution of this dissertation (Section 5.2) and providing recommendations for future research (Section 5.3).

## 5.1 Research summary

The primary aim of this research was to develop a methodology for modelling sectorally and regionally disaggregated freight flows in emerging economies in the absence of formal interrogable statistics on the freight transport market. This is enabled by leveraging existing data sources and successfully applying the outputs to inform macrologistics decision-making. A resulting secondary aim was to contribute to the body of knowledge in the developing field of macrologistics in general, and specifically how it relates to emerging economies. These research aims were achieved through addressing the following research objectives:

- Establishing the rationale for an explicit focus on macrologistics;
- Developing a methodology for the development of DNFDMs in emerging economies; and
- Illustrating the utility of the outputs from the DNFDMs through application in:
    - Data-driven macrologistics policy formulation and investment prioritisation in support of macroeconomic goals; and
    - Re-imagining macrologistics value chain development.

The results from the DNFDMs of four emerging economies, namely South Africa, India, Uzbekistan and Mongolia were used as proof-of-concept to reach these objectives.

In **Chapter 1**, the rationale for an explicit focus on macrologistics was established. Over the past two decades, logistics' role evolved beyond trade-offs between logistics functions to trade-offs between business functions towards total cost of ownership trade-offs, first for companies, then total supply chains and finally value chains. The trade-off role eventually shifted to globalised supply chains enabled by new transport and information technologies, where society in effect made the trade-off in favour of additional logistics costs to support scale economics and economic growth. We are in the midst of a revision of this trade-off where ecological and societal parity with the economic growth focus is at least desirable, if not inevitable. This necessitates a novel view of logistics' trade-off role, what is increasingly being referred to as macrologistics, i.e. to lower the total cost of ownership of goods on a macroeconomic scale to improve societal wellbeing and ecological sustainability, implemented through balanced logistics policy, appropriate infrastructure provision and systemic management. This pervasive trade-off characteristic of logistics necessitates the availability of data – i.e. detailed information on transport and its underlying factors based on the interrelations between the transport sector and the rest of the economy. In emerging economies, where macrologistics information is needed the most due to high levels of investment required with a simultaneous high impact, this information is scarce and difficult to develop.

The candidate's contribution is specifically in the development of a practical macrologistics instrumentation construct for emerging economies, i.e. the quantification of commodity-level, spatially-disaggregated freight-flow models *based on data available in the local economy*, referred to as disaggregated national freight demand models (DNFDMs).

The principles of grounded theory provided the inspiration for the development of the DNFDM research methodology in data-scarce environments, as presented in **Chapter 2**. Grounded theory is the discovery of theory from data which is systematically obtained and analysed, for the purposes of improved practical understanding, analysis and prediction, and for advancing theory without preconceived outcomes or a priori assumptions. The key principles of grounded theory that informed the research approach in this dissertation are a general method of comparative analysis, i.e. systematic and simultaneous discovery, collection, coding and analysis of a variety of data sources, reinforced by targeted sampling until data saturation is reached. The latter refers to a set of supply and demand matrices, decay factors and road networks that will unlock the aforementioned freight flow instrumentation. The novelty of the methodology is that a standardised construct has been developed that targets the use of available statistics in emerging economies (where comprehensive commodity flow surveys are not available) to populate regionally and sectorally disaggregated supply and demand tables for the whole economy under question. A further methodological contribution is macrologistics market segmentation, i.e. the link between freight flows and the basic economic value chain, and what this means for macrologistics service provision. The output is the classification of freight into logistically sensible segments for the purposes of policy and investment prioritisation, while also providing a simplified narrative of a nation's macrologistics strategy.

As presented in this dissertation, the methodology has been successfully applied in South Africa, India, Mongolia and Uzbekistan. In addition, a provincial extension was developed in South Africa and a regional model for sub-Saharan Africa (excluded from the scope of this dissertation due to the national focus). In all cases the methodology proved sound, the population of supply and demand tables was possible, and the outputs added significant value to country-level understanding of the national, regional and industry-level freight-flow landscape, informing data-driven policy and infrastructure investments as discussed in **Chapter 3**. For each case study country, priority macrologistics interventions were identified that, if diligently verified and implemented, can make a significant shift in the country's macrologistics landscape and unlock resources for addressing subsequent priority areas. For South Africa, these initially pertain to the introduction of domestic intermodal solutions on the country's two most dense corridors (which will reduce domestic and international trade transport cost, as well as externality costs), and the densification of branch lines which will improve economic, environmental and social outcomes in rural areas. For India, the priority area is support for the country's dedicated freight corridor initiatives, with the first case study the country's most dense corridor, the Eastern Corridor, resulting in an integrated proposal for an extended gate for the port of Kolkata and a logistics hub outside of Kolkata with a high-volume link into the city. For Uzbekistan, the DNFDM outputs support the development of SEZs, identify rail utilisation and improvement opportunities, and inform the development of a transport strategy for Uzbekistan to leverage its role in Central Asia.

Lastly, in **Chapter 4,** the outputs of DNFDMs enabled the development of macrologistics solutions for a specific value chain and a logistics technology serving a specific value chain. The two case studies – a structural and spatial reconfiguration of Mongolia's livestock value chain and domestic intermodal solutions for South Africa's FMCG industry – highlight that spatial and commodity disaggregation of freight flows enable identification of value chain bottlenecks and opportunities. Value chains can be optimised through collaboration and densification, of which practical execution such as logistics hubs or freight villages can be optimally informed through freight-flow analysis.

## 5.2 Unique contribution

As discussed in the previous section, the shift towards a macroeconomic trade-off role for logistics, i.e. macrologistics, necessitates the availability of appropriate data, especially in emerging economies where macrologistics issues are more pressing, and codified data and analytical tools are insufficient.

The candidate's contribution is in the development and interpretation of a practical macrologistics instrumentation construct for emerging economies, i.e. the quantification of commodity-level, spatially-disaggregated freight-flow models *based on data available in the local economy*, referred to as disaggregated national freight demand models (DNFDMs). The level of disaggregation in the freight-flow model, and the flow-level link with a logistics costs model, within the context of the national input-output model (or economic aggregates where I-O models are not available), is to the best of the candidate's knowledge unique. The link to trusted actual data (on industry, modal, trade and economic aggregate level) improves the quality of and confidence in both the inputs and outputs, and bridges logistics' analytical gap to macroeconomic decision-making.

In terms of the research approach to develop and execute the DNFDM methodology, the candidate's contribution is the application of grounded theory principles in secondary quantitative analysis, emphasising the possibility that through creativity, cooperation and with a practical output in mind, emerging economies do not have to be paralysed by theoretical models, the absence of formal freight-flow statistics or an inability to successfully conduct and extrapolate CFSs. It is possible through iterative comparative analysis and targeted sampling (including stakeholder engagement) to integrate multiple overlapping or contradicting data sources and to select appropriate proxies where complete or disaggregated data does not exist, with the boundary condition of actual data as mentioned above, and then apply the 'saturated data' (refer Chapter 1) to model freight flows.

The standardised outputs generated by DNFDMs, namely geographically and sectorally disaggregated supply and demand data, which result in freight flows with the primary parameters of origin, destination, commodity, volume of freight and transport mode, pave the way for tracking logistics' performance as a regular macroeconomic indicator in order to improve the management of the transport and logistics sector within the context of the macro economy. Standardised outputs also render these indicators comparable across countries irrespective of various data inputs.

In summary, whereas passenger flow modelling is a relatively mature field (having been formally studied since the 1960s [De Jong et al., 2004]), macrologistics freight flow modelling is a relatively recent concept that still requires further research to formalise and strengthen the field. Within this reality a few major issues are arising i.e. existing methodologies that are considered require a standardised and often difficult-to-obtain set of input data, are expensive and time consuming and due to these limiting factors produce results that are not comparable amongst nation states or regions. The approach presented in this dissertation can overcome these challenges for emerging economies while still providing a comparable macrologistics tool with standardised outputs (rather than inputs) that can inform strategy, policy and infrastructure creation.

In terms of the application of the DNFDM methodology itself, an important contribution is in the development and refinement of the fundamental parameters of the gravity model, i.e. the decay factors and the road network (rail data and the rail network are typically available from a single operator due to the single-network characteristic of rail still prevailing in emerging economies). In a doubly-constrained gravity or spatial interaction model where both the origins and destinations are known but the derived freight flows over the road transport network are unknown, the problem is essentially confined to the estimation of a suitable decay parameter. The candidate develops a distance-decay parameter for each commodity group in each economy individually to account for the varying nature and utility of the commodity (based on the grounded theory principles discussed in this dissertation). Sample known flows, knowledge from industry experts, and even public information about commodities and sectors can inform transport behaviour, and the relative suitable decay factor. The decay factor is also dynamic and can, through the application of various regression tools, inform improvements required by structural changes in an economy. Accuracy of distribution modelling is enhanced by the creation of a road distance matrix (by the candidate) to determine the flow data for the non-rail component of freight. A detailed national road network is constructed, allowing road travel times to be estimated between the various origins and destinations, penalised for the type of road. A lower resistance is given to national roads, so freight collates towards these highways, the logic being assumed improved travel time on highways. Resistance is adjusted by ranking roads through reducing the travel distance for highways and increasing the travel distance for rural roads. These adjustments improve modelling accuracy.

## 5.3 Suggestions for future research

With regards to the DNFDM methodology, the following areas can be investigated:

- **The modelling of short-distance movements** (i.e. intra-district and intra-metropolitan movements). It is not possible with the current methodology to distinguish short-distance movements, as gravity modelling is not suited for micro-level modelling. Detailed vehicle routing can therefore not be distilled from the current methodology as via points and freight deconsolidation/consolidation centres cannot be added. A possible solution would be to combine agent-based modelling with gravity modelling. The gravity model will then be set up to distribute freight to DCs (or via points), while the truck trips generated through agent-based modelling (via e.g. GPS data), can be enhanced with a commodity view obtained from the gravity model. The integration of these two approaches is being researched. An article incorporating a first attempt of this research has recently been submitted to the South African Journal of Industrial Engineering and is under review[15].
- **Refinement of gravity modelling:** (1) A sensitivity analysis to establish the impact on flow outputs of changes in geographically disaggregated supply and demand data vs. the impact on flow outputs of alternative decay factors in order to determine priorities for future research. (2) The use of a combination decay factor is being considered for specific homogenous goods, with distance decay up to a set distance, combined with a biased attraction point from the set distance to allow for higher flows on key trades, while variable decay factors for exports vs. domestic demand are being developed. (3) Variable centroids per geographical area are being investigated to account for the location of agriculture production vs. the location of intermediate and final demand in the same geographical area. (4) Incorporating the distribution of known flows during the flow modelling process is being explored, as the attraction between these flows will impact the iterative flow modelling process.
- **The regionalisation and globalisation of the process.** The candidate led research teams and published work on regional transport models in sub-Saharan Africa prior to registering for the PhD (refer King et al., 2016). The experienced gathered from this research can be used to enhance and strengthen this work in notable global regions, such as sub-Saharan Africa, South East Asia and the Belt and Road Initiative, all geographical areas that the candidate's research has already touched upon. Finally a global dimension is inevitable. The ITF (International Transport Forum, 2020) developed a global model and the candidate's future work should either connect with this or potentially create an alternative to enhance and grow the field of freight transport modelling.

[15] The submitted article is titled "Dynamic OD estimation for freight vehicles: A case study – Kolkata city logistics", authored by Swarts S.J., Simpson, Z.P. and Havenga, J.H. This article was submitted in February 2021, and it discusses a freight-flow model developed for the megacity of Kolkata based on supply-side modelling (a market survey and truck counts). Kolkata is a critical link in India's Eastern Corridor (refer Chapter 3). The research indicates that a combination of supply- and demand-side freight flow modelling renders rich insight into inner-city freight flow challenges (supply-side modelling), as well as linkages with the broader economy (demand-side modelling).

- **The forecasting of freight flows.** Forecasts have been developed for South Africa's DNFDM but not yet for the other emerging economies. This is an important extension to track shifts in the economic structure of the economies and to ensure the relevance of infrastructure investments.
- **Logistics costs.** Refining the logistics costs models for India, Uzbekistan and Mongolia in order to support the development of a standardised construct similar to the DNFDMs.

In terms of the broader macrologistics discipline, the shift towards economic, ecological and social parity is increasingly being investigated. In the econosphere it is necessary to optimize value chains, especially in emerging economies, where existing industries are being redefined and new industries are being established, all with concomitant infrastructure and logistics impacts (refer for example the case studies in Chapter 4). Optimal policy and infrastructure should be informed by data-driven requirements which should include physical flows, now and in the future. In the sociosphere, humanitarian logistics is estimated to comprise 80% of the cost of humanitarian aid (Cozzolino, 2012). The search for a global relief strategy around hunger, disease and disaster includes logistics as the most important element, and macrologistics should be able to answer questions such as where to place depots and warehouses, how much inventory to have in place, and how to transport this to those in need. In the biosphere, strategies and pathways to decarbonisation is required (McKinnon, 2016). This is expected to include, *inter alia,* the measurement of emissions from all logistics activities, which by definition presupposes an understanding of economic activities and related flows in the most disaggregated way possible.

An important aspect here is that, even though the world is regionalising, developing an understanding of global flows is critical due to the size of unregulated flows – maritime transport for example, amounted to 70% or 75 trillion tonne-km of the total tonne-km transported worldwide in 2015 (International Transport Forum, 2019). The nature of land flows influences these maritime flows.

The relevance here is that in order to provide an input into addressing these challenges, macrologistics can and should model the status quo, requirements and implementation scenarios – on freight-flow level in as much detail as possible, and with flow-level links to costing. Relative to the cost of interventions in any of these areas, focused modelling attempts at the outset will have a negligible cost impact, but can have a significant impact on the efficiency of interventions.

# Chapter 6. Bibliography for references used in bridging text

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# Appendix A: Contribution declarations

## A.1 Chapter 2 declaration

**Declaration by the candidate:**

With regard to the published article

***Macrologistics instrumentation: Integrated national freight-flow and logistics cost measurement***

included in Chapter 2 (pages 14-26), the nature and scope of my contribution were as follows:

| Nature of contribution | Extent of contribution (%) |
|---|---|
| The candidate conceptualised the new version of the freight demand model, did the mathematical analysis and produced the results. The candidate also presented the results at international conference and incorporated feedback into the final version | 33.3% |

The following co-authors have contributed to the published article included in Chapter 2 (pages 14-26):

| Name | e-mail address | Nature of contribution | Extent of contribution (%) |
|---|---|---|---|
| Prof Jan Havenga | janh@sun.ac.za | Project guidance and mentorship | 33.3% |
| Ilse Witthöft | ilsew@sun.ac.za | Writing and content editing | 33.3% |

Date and signature of candidate: *Declaration with signature in possession of candidate and supervisor.*

**Declaration by the co-authors:**

The undersigned hereby confirm that

1. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to the published article included in Chapter 2 (pages 14-26)
2. no other authors contributed to published article included Chapter 2 (pages 14-26) besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in Chapter 2 (pages 14-26) of this dissertation.

| Name | Signature | Institutional affiliation | Date |
|---|---|---|---|
| Prof Jan Havenga | | Stellenbosch University | 26 Feb 2021 |
| Ilse Witthöft | | Stellenbosch University | 26 Feb 2021 |

**Declaration by the candidate:**

With regard to the published book chapter

# ***A methodology for spatially and commodity-level disaggregated national freight demand modeling in emerging economies***

included in Chapter 2 (pages 28-57), the nature and scope of my contribution were as follows:

| **Nature of contribution** | **Extent of contribution (%)** |
|---|---|
| The candidate related the the freight demand in new environments with specific focus on emerging economies. Learnings from various countries were incorporated to strengthen the mathematical and statistical foundation of the modelling and make the results more relative for a broader audience. | 75% |

The following co-authors have contributed to the published book chapter included in Chapter 2 (pages 28-57):

| **Name** | **e-mail address** | **Nature of contribution** | **Extent of contribution (%)** |
|---|---|---|---|
| Prof Jan Havenga | janh@sun.ac.za | Project guidance and mentorship | 5% |
| Ilse Witthöft | ilsew@sun.ac.za | Writing and content editing | 15% |
| Dr Bernard Aritua | baritua@worldbank.org | Project sponsorship and strategic inputs | 5% |

Date and signature of candidate: *Declaration with signature in possession of candidate and supervisor.*

**Declaration by the co-authors:**

The undersigned hereby confirm that

1. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to the published book chapter included in Chapter 2 (pages 28-57),
2. no other authors contributed to published book chapter included Chapter 2 (pages 28-57) besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in Chapter 2 (pages 28-57) of this dissertation.

| Name | Signature | Institutional affiliation | Date |
|---|---|---|---|
| Prof Jan Havenga | | Stellenbosch University | 26 Feb 2021 |
| Ilse Witthöft | | Stellenbosch University | 26 Feb 2021 |
| Dr Bernard Aritua | | World Bank | 26 Feb 2021 |

## A.2 Chapter 3 declaration

**Declaration by the candidate:**

With regard to the published book chapter

***Spatially and commodity-level disaggregated freight demand modelling in emerging economies: Applications for South Africa and India***

included in Chapter 3 (pages 63-95), the nature and scope of my contribution were as follows:

| **Nature of contribution** | **Extent of contribution (%)** |
|---|---|
| The candidate used the research to demonstrate new dimensions of freight flow segmentation and strategy development. The work included statistical analysis, conceptualisation and the development of segment strategies. | 75% |

The following co-authors have contributed to the published book chapter included in Chapter 3 (pages 63-95):

| **Name** | **e-mail address** | **Nature of contribution** | **Extent of contribution (%)** |
|---|---|---|---|
| Prof Jan Havenga | janh@sun.ac.za | Mentorship | 5% |
| Ilse Witthöft | ilsew@sun.ac.za | Writing and editing | 15% |
| Dr Bernard Aritua | baritua@worldbank.org | Project sponsorship and strategic guidance | 5% |

Date and signature of candidate: *Declaration with signature in possession of candidate and supervisor.*

**Declaration by the co-authors:**

The undersigned hereby confirm that

1. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to the published book chapter included in Chapter 3 (pages 63-95),
2. no other authors contributed to published book chapter included Chapter 3 (pages 63-95) besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in Chapter 3 (pages 63-95) of this dissertation.

| Name | Signature | Institutional affiliation | Date |
| --- | --- | --- | --- |
| Prof Jan Havenga | | Stellenbosch University | 26 Feb 2021 |
| Ilse Witthöft | | Stellenbosch University | 26 Feb 2021 |
| Dr Bernard Aritua | | World Bank | 26 Feb 2021 |

## A.3 Chapter 4 declaration

**Declaration by the candidate:**

With regard to the article ready for submission

***Value chain analysis for infrastructure investment planning: the case of the Mongolian livestock value chain***

included in Chapter 4 (pages 132-163), the nature and scope of my contribution were as follows:

| Nature of contribution | Extent of contribution (%) |
|---|---|
| The candidate developed the freight flow model for Mongolia on which the work was based, conceptualise the value chain involved and were responsible for all the statistical analysis. | 55% |

The following co-authors have contributed to the article included in Chapter 4 (pages 132-163):

| Name | e-mail address | Nature of contribution | Extent of contribution (%) |
|---|---|---|---|
| Dr Bernard Aritua | baritua@worldbank.org | Project sponsorship and strategic guidance | 8% |
| Dr Esbeth van Dyk | esbethvandyk@gmail.com | Developing theoretical context, writing and editing | 8% |
| Dr Isabel Meyer | iameyer@me.com | Developing theoretical context, writing and editing | 8% |
| Stefaan Swarts | stefaan@sun.ac.za | Statistical analysis | 8% |
| Jaap van der Merwe | jaap.vdm@powerlawcapital.com | Logistics strategy and vale chain inputs | 8% |
| Prof Jan Havenga | janh@sun.ac.za | Mentorship and guidance | 5% |

Date and signature of candidate: *Declaration with signature in possession of candidate and supervisor.*

**Declaration by the co-authors:**

The undersigned hereby confirm that

4. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to the article included in Chapter 4 (pages 132-163),
5. no other authors contributed to article included Chapter 4 (pages 132-163) besides those specified above, and
6. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in Chapter 4 (pages 132-163) of this dissertation.

| **Name** | **Signature** | **Institutional affiliation** | **Date** |
|---|---|---|---|
| Dr Bernard Aritua | | World Bank | 24 Feb 2021 |
| Dr Esbeth van Dyk | | Stellenbosch University | 24 Feb 2021 |
| Dr Isabel Meyer | | Stellenbosch University | 23 Feb 2021 |
| Stefaan Swarts | | Stellenbosch University | 23 Feb 2021 |
| Jaap van der Merwe | | PowerLaw Capital | 23 Feb 2021 |
| Prof Jan Havenga | | Stellenbosch University | 23 Feb 2021 |

**Declaration by the candidate:**

With regard to the submitted article

# ***Intermodal solutions for the South African fast-moving consumer goods sector***

included in Chapter 4 (pages 165-187), the nature and scope of my contribution were as follows:

| **Nature of contribution** | **Extent of contribution (%)** |
|---|---|
| The candidate did all the underlying modelling and statistics required for this work and developed the segmentation model on which the work is based | 35% |

The following co-authors have contributed to the submitted article included in Chapter 4 (pages 165-187):

| **Name** | **e-mail address** | **Nature of contribution** | **Extent of contribution (%)** |
|---|---|---|---|
| Anneke de Bod | annekedb@sun.ac.za | Project management | 10% |
| Prof Jan Havenga | janh@sun.ac.za | Guidance and mentorship | 5% |
| Dr Isabel Meyer | iameyer@me.com | Writing and editing | 25% |
| Dr Esbeth van Dyk | esbethvandyk@gmail.com | Writing and editing | 25% |

Date and signature of candidate: *Declaration with signature in possession of candidate and supervisor.*

**Declaration by the co-authors:**

The undersigned hereby confirm that

1. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to the submitted article included in Chapter 4 (pages 165-187),
2. no other authors contributed to submitted article included Chapter 4 (pages 165-187) besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in Chapter 4 (pages 165-187) of this dissertation.

| Name | Signature | Institutional affiliation | Date |
|---|---|---|---|
| Anneke de Bod | | Stellenbosch University | 24 Feb 2021 |
| Prof Jan Havenga | | Stellenbosch University | 23 Feb 2021 |
| Dr Isabel Meyer | | Stellenbosch University | 24 Feb 2021 |
| Dr Esbeth van Dyk | | Stellenbosch University | 24 Feb 2021 |

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